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Associations Between the Perceived and Built Food Environment

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DEDICATION

I would like to dedicate this dissertation to my deceased grandparents, Marie J. Barnes and Lamar G. Barnes, Sr., both for whom were instrumental in raising and molding me into the person I have become today.

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and graduate degrees. I would not be who I am and who I hope to be without continued guidance and blessings.

ABSTRACT

Neighborhood food environments have been associated with dietary intake and obesity. Measures of the food environment have typically been characterized with geographic information systems (GIS)-based measures, however, the use of perception-based measures of the food environment have increased in frequency. Few studies have fully examined the relationship between perceptions and GIS-based measures of the food environment, especially considering the congruency between perceived and GIS-based presence of specific retail food outlets, nor the relationship between food outlets and perceived availability of healthy foods or fast food opportunities.

Telephone survey data from 705 residents in an eight-county region of South Carolina were used to examine the relationship between GIS-based measures of food outlets and residents' perceptions. Perception measures included the residents' perceived availability of specific food outlets types (including supermarkets and fast foods), the availability of healthy foods (fresh fruits and vegetables and low fat foods), and the availability of fast food restaurants. GIS-based measures include the actual presence (yes or no) of food outlets within each resident's neighborhood and the availability (number of) and accessibility (distance to nearest) to specific food outlets.

Significant findings indicate residents' perceived the presence of food outlets in their food environment quite well with percent agreements, present or not, for food outlets ranging from 67.1% to 83.5%. Sensitivities ranged from 82.3% to 92.5% with

supermarkets and convenience stores having excellent values (92.5% and 90.1%, respectively). However, the availability (number of) food outlets in a neighborhood did not have a significant association with perceived availability of healthy foods, whereas accessibility (distance to the nearest), specifically for supermarkets, dollar and variety stores, and fast food restaurants, was significantly associated with perceptions of healthy foods. Lastly, only the availability and accessibility of drug and pharmacy stores and accessibility of supermarkets were significantly associated with perceived fast food availability. Additional analyses examined urban and non-urban residents separately.

Findings suggest that residents are quite aware of the presence of food outlets in their food environment, however, many of the associations between GIS-based availability and accessibility of food outlets and perceived availability of healthy foods and fast food opportunities are not significant. Factors such as the size and urbanicity of a residents' GIS-based neighborhood may affect associations between perceived and GIS-based measures.

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LIST OF ABBREVIATIONS

BRFSS..... Behavioral Risk Factor Surveillance System

CDC ..... Centers for Disease Control and Prevention

GIS ..... Geographic Information Systems

SNAP ..... Supplemental Nutrition Assistance Program

CHAPTER 1

INTRODUCTION

Over the past thirty years, the prevalence of obesity and overweight in the United States has more than doubled and but recently has leveled off (1) (2) (3) (4) (5) (6) (7) (8). Currently, more than two-thirds of adults and approximately one-third of children and adolescents in the United States are overweight or obese, with some minority and low socioeconomic groups disproportionally affected (8). Obesity has been linked to increased morbidity and mortality (9) (10) and has become the second preventable cause of disease and mortality in the United States, second only to tobacco use (3) (8). Similar trends have been reported in other industrialized countries (4).

With the increased obesity prevalence in the United States, it has become more important than ever to understand the underlying causes. In most individuals, weight status is a result from excess calorie consumption and inadequate physical activity, however, there are many other factors including environment, social dynamics, and genetics that contribute to and influence energy balance (11) (12). Many socio-ecological models have been developed to guide researchers in studying these different factors contributing to the obesity epidemic (11) (13) (14) (15) (16) (17) (18) (19). These models or conceptual frameworks have developed into a predominate theme in which different influences can impact an individual's food choice, behaviors, and, ultimately, health outcomes.

One such influence has been the built food environment in which the availability and accessibility to specific food outlet types such as supermarkets and grocery stores have been shown to be associated with dietary behavior, weight status, and health outcomes (20) (21) (22) (23) (24) (25). Moreover, studies focusing on the food environment have shown that increased availability of supermarkets and grocery stores near an individual's home is associated with increased consumption of fruits and vegetables, a general healthier diet, and decreased risk of overweight and obesity (20) (21) (26) (27) (28) (29) (30) (31) (32) (33) (34). Research also suggests that individuals who have limited access to less healthy food outlets such as convenience stores tend to have healthier diets and lower levels of obesity (20). When examining access to fast food and restaurants, results are less consistent; however, some studies suggest that individuals with limited access to fast food restaurants also have healthier diets and lower levels of obesity (20) (23) (35).

Given these findings, new public health policies and initiatives have been established to address availability and accessibility of healthier food options in communities (21) (36) (37) (38) (39). In addition, efforts have been made to address disparities in food access via targeting defined "food deserts" and underserved communities (21) (36) (37) (38) (39).

Although findings of food environment research have shown significant associations between food outlet availability and accessibility with dietary intake and obesity prevalence, there are still problems when examining these relationships. Issues with current findings include the assumption that increased availability and access to healthy food options and food outlet types will directly translate to the awareness and

utilization of those food options and outlets in an individual's neighborhood food environment. Thus, if an individual has a supermarket available in their neighborhood it is assumed that this will translate being aware or perceiving the existence of that supermarket and ultimately choosing to shop at that particular food outlet. In addition, there is the assumption that increased availability and accessibility of certain food outlet types such as supermarkets and grocery stores correspond to increased availability of healthier food options (21) (40).

The built food environment has predominately been characterized objectively using commercial databases and geographic information systems (GIS) (20) (30) (41) (42). Two types of measures are usually used to assess the food environment in GIS: density and proximity. Density is the number of food outlets in a defined area and proximity is the distance between a specific location and the closest food outlet (42) (43). GIS-based measures of the food environment can also be discussed in terms of availability and accessibility. Availability is typically defined in food environment research as the presence or density of food retail outlets in a defined area (42) (43) (44) e.g. count of supermarkets and grocery stores within a census tract or block group. Accessibility has been defined as the ease of access to available food options and outlets taking into consideration factors such as travel distance, time, and/or financial resources (43). In food access research, distance to the nearest food retailer i.e. proximity has been the most common approach. However, accessibility has also been characterized by several other measures including: 1) the cumulative opportunity measure, 2) gravity based measures, and 3) random utility-based measures (43).

Although, objective measures are typically the gold standard in food environment assessment measures, researchers have been concerned that an individual's perceptions of the food environment may be just as important, either as a better predictor or a mediator between the actual built food environment and dietary behavior and health outcomes (30) (41) (45). Moreover, theoretical models and studies of environments and eating behaviors have recently considered specific food environment perceptions as an important determinant in mediating the pathway between the actual food environment and what people eat (45).

This dissertation sought to address the association between the built food environment and perceived measures of healthy food options and food outlet types. Others have already begun to investigate the association between the built food environment and perceived measures of food availability and access (46) (47) (48) (49) (50) (30) (51) (52) (53) (41) (54) (55) (56) (57) (53) (53) (45) demonstrating interesting results. For example, Moore and colleagues (2008) have shown that a greater density of supermarkets within a mile of an individual's home corresponds to a better perceived availability of healthy food options compared to individuals with low or no density of supermarkets (50). However, Gustafson and colleagues have provided mixed and contrary findings in which individuals who lived in areas with a convenience store and a supercentre had increased odds of perceiving their neighborhood high in availability of healthy foods than individuals with no store (53). Only one study has considered how the actual and perceived food environment varies by socio-economic characteristics (45). No study has examined how the relationship between the built and perceived food

environment varies when using different geographical boundaries to define a person's neighborhood.

By investigating the association between the built and perceived food environment, researchers will have a better understanding on how to best inform health policies. Thus, are GIS-based availability of food options sufficient in public health policy and interventions or does an individual's perceptions also play a role? Some researchers have already begun to look into whether spatial food access measures are mediated through perceptions of the food environment (50) (28) (58) (59).

The goal of this dissertation research is to improve the understanding of the association between the objective measure of a person's neighborhood food environment and the perception of the neighborhood food environment. This will build on previous research that ultimately aims to improve access to healthy food options, dietary intake quality, and health outcomes.

The specific aims are the following:

Specific Aim 1: Compare the perceived and GIS-based presence of various food outlet types (e.g. supermarkets, supercenters, small grocery stores, convenience stores, dollar and variety stores, drug stores and pharmacies, and fast food restaurants) in an individual's neighborhood food environment.

Specific Aim 2: Examine the association between the perceived availability of healthy foods (fresh fruits and vegetables and low fat products) in an individual's neighborhood and the GIS-based availability and accessibility measures of specific food outlet types

(e.g. supermarkets, supercenters, small grocery stores, convenience stores, dollar and variety stores, drug stores and pharmacies, and fast food restaurants) in an individual's neighborhood food environment. (Does the GIS-based food outlet type availability or accessibility predict or influence the perceived availability of healthy food options?)

Specific Aim 3: Examine the association between the perceived availability of fast food opportunities in an individual's neighborhood and the GIS-based availability and accessibility measures of fast food restaurants in an individual's neighborhood food environment.

Specific research questions related to these aims include:

Research Question 1: To what extent does the perceived presence agree with the actual presence of the food outlet types using a standard 1 mile network buffer to define an individual's built neighborhood food environment?

Research Question 2: How does agreement change between the actual and perceived food outlet types' presence when varying the network buffer used to characterize the built neighborhood food environment? (Does the agreement change when using a larger, 2, 3, or 5, mile network buffer to define an individual's built neighborhood food environment?)

Research Question 3: Is perceived availability of healthy foods (fresh fruits and vegetables and low fat products) in an individual's neighborhood associated with the GIS-based availability and accessibility measures of healthier food outlet types (supermarkets, supercenters, and small grocery stores) in an individual's neighborhood food environment?

Research Question 4: Is the availability and accessibility of less healthy food outlet types (convenience stores, dollar and variety stores, drug stores and pharmacies, and fast food restaurants) associated with the perceived availability of healthy foods?

Research Question 5: How do the association between GIS-based availability and accessibility measures of healthier food outlet types and perceived availability of healthy foods change when controlling for less healthier food outlet types?

Research Question 6: Is perceived availability of fast food opportunities associated with GIS-based availability and accessibility measures of fast food restaurants in an individual's neighborhood food environment?

Research Question 7: How do the associations change when controlling for GIS-based availability and accessibility measures of other food outlet types?

This research can inform policy makers and other researchers in whether their research should include both objective and subjective measures of the food environment. If findings suggest there is moderate or good agreement (concordance) between perceived presence of food outlet types and the objectively measured built food environment then this would suggest that individuals have a good picture of what stores and restaurants are in their neighborhood food environment and would allow researchers to focus on other individual-level factors which may influence a person's utilization of their neighborhood food environment and how that relates to their diet and health outcomes. However, if there is poor concordance between perception and reality then that would leave a question of why individuals do not accurately perceive their neighborhood food environment. Public health researchers would need to be concerned

that individuals are not properly informed and educated about their neighborhood surroundings. Or it could be the case individuals are aware of food outlets, but the quality of food items is poor.

Additionally, the findings of this dissertation could have implications for previous research that assumes GIS-based availability or accessibility to food outlets is a good proxy of "healthy food options" in a person's neighborhood food environment. This dissertation aims to examine whether individuals' perceptions of healthy food options are associated with the GIS-based measures. This is an important relationship to study because it is possible for individuals to perceive the availability of healthy food options or fast food opportunities positively, however, live in a neighborhood with few or no food outlets. Moreover, these individuals may travel outside of their area or have their perception influenced by other individual or neighborhood-level factors. The goal of this dissertation is to disentangle some of the possible associations between the perceived and built food environment. Results of this dissertation may assist researchers to decide whether perception-based or GIS-based measures are sufficient to characterize a person's neighborhood environment and help policy-makers select appropriate means in which to combat food inequalities and improve eating habits in populations. The complete dissertation findings are presented in three distinct manuscripts.

Definitions

Perceived Food Environment – Defined by a previously validated instrument which has been applied in the MESA Neighborhood Study (60). The purpose of the instrument was to measure the perceived availability of healthy foods (fresh fruits and vegetables and

low fat products; lack of fast food opportunities) within a person's neighborhood defined as 1 mile buffer or 20 minute walk. In addition, information on the perceived presence (availability) of various food outlet types in each participant's neighborhood, as a measure of awareness on the part of the resident was collected.

Built Food Environment – The verified existence (presence, geographic location, and type) of various food outlets within an eight-county study region of South Carolina through data validation and field census (61). Availability and accessibility measures were calculated based on this data collection.

Individual and Neighborhood-Level Demographic and Socio-economic Factors –

Individual-level demographic and socio-economic characteristics included age, sex, race/ethnicity, household income, level of education, marital/partner status, and number of individuals living in the home. These questions were based and taken directly from the established Behavioral Risk Factor Surveillance System (BRFSS) survey (62). Neighborhood-level urbanicity was also determined using the 2010 U.S. Census defined urban classification (63).

Hypotheses

There are many hypotheses related to the aims of this dissertation. Related to Aim 1, it is hypothesized that individuals will have a moderate (40 – 60%) agreement between the perceived and GIS-based presence of food outlet types with supermarkets having the best agreement. Agreement between individuals' perceived and GIS-based

presence of food outlet types will improve (increase) with increasing built neighborhood buffer size. The examination of varying neighborhood size definitions was included in this dissertation to assess if a one mile buffer size matched the boundaries that participants used to define their local food environment. It is possible that participants have overestimated the size of their neighborhood environment as defined in the survey and included food outlets not actually present within the one mile boundary. In physical activity research, the use of different boundaries to define neighborhood has been examined and suggests that potential differences in relevant neighborhood areas across environmental features and population subgroups i.e. rural versus urban neighborhoods exist (64) (65) (66).

For Aim 2, it is hypothesized that there will be a positive association between the perception of healthy foods and the availability and accessibility of healthy food stores. Contrarily, it is hypothesized there will be a negative association between the perception of healthy foods and the availability and accessibility of "less healthy" food outlet types such as convenience stores, drug and pharmacies, dollar and variety, and fast food restaurants. When taking into account neighborhood factors, individuals living in non-urban versus urban environments will have poor associations between the perceived and GIS-based food environments given the disparity between food outlet availability and accessibility between urban and non-urban communities. It is hypothesized for Aim 3 that there will be a positive association between perceived availability of fast food opportunities and availability and accessibility of fast food restaurants.

CHAPTER 2

BACKGROUND

Overview

A relationship between food environments, dietary consumption, and health outcomes including obesity has been well established in the literature (20) (21) (26) (27) (28) (29) (30) (31) (32) (33) (34). Moreover, techniques and concepts in measuring the food environment have also been described (20) (67) (42) (43). This chapter will review and discuss the literature as it relates to the importance and relevance of studying the food environment, key findings and associations established, and how perceptions of an individual's perception of their food environment may have a role in the conceptual framework involving the food environment and dietary intake.

The Built Environment

During the past decade, a shift in research has occurred in which the contribution of environments and places to the health and health-related behaviors in individuals has become the center of attention (68) (69) (70). It is thought that to understand those factors that influence behavior and health, it will be necessary to describe the context and setting of an individual's neighborhood, work, and other physical and social environments (11) (70) (71).

The Centers for Disease Control and Prevention (CDC) have defined the environment as ‘‘all that is external to the individual”, with the term ‘‘built environment’’ encompassing aspects of a person’s surroundings which are human-made or modified, as compared with naturally occurring aspects of the environment (71). Moreover, the many ways in which the built environment influences health include not only ‘‘direct pathological impacts of various chemical, physical, and biologic agents, but also factors in the broad physical and social environments, which include housing, urban development, land use, transportation, industry, and agriculture’’ (71). In a review, Papas and colleagues (2007) suggest that understanding the impact of specific components of the environment may provide vital information necessary to develop successful community-based prevention efforts related to obesity and other chronic diseases (11). Thus, researchers should explore the many different built environments to which humans are exposed across their day-to-day lives. Environments of consideration include residential space and activity space, as well as the connection between the two spheres (11). For children, this has included school and recreational space. For adults, environments of interest have included residential space, work space, and characteristics of the travel environment between work, shopping, and personal business, social and recreational activities and the residence (11) (71).

Evidence provides a supportive argument that environment is associated with overweight and obesity (11) (72) (73) (74) (75) (27) (76) (77) (78) (79) (80). Moreover, the built environment has become an important influence in creating a climate that promotes increased energy consumption (increased food intake) and a reduction in energy expenditure (decreased physical activity) (11).

Obesity, Health Outcomes, and Diet

The prevalence of obesity and overweight has increased dramatically in the United States in the past thirty years, with recent surveys reporting that two thirds of adults are overweight or obese (3) (5) (6). Among children and adolescents, the prevalence of overweight has tripled since 1980 (7) (4). By 2015, it is projected that 75% of adults will be overweight or obese, and 41% will be obese (8). The data also show that overweight and obesity do not affect all populations equally, with higher rates generally found for Non-Hispanic Black Americans and Mexican Americans compared to Non-Hispanic White Americans (4,8). International obesity rates are not as high as those reported in the United States; however similar trends have been reported in other industrialized countries (4). Obesity has been linked to increased morbidity and mortality (9) (10) and has become the second preventable cause of disease and mortality in the United States, second only to tobacco use (3) (8). Moreover, individuals that are obese have increased risk of numerous co-morbidities including type 2 diabetes mellitus, hypertension, hypercholesterolemia, hypertriglyceridemia, cardiovascular disease, stroke, osteoarthritis, obstructive sleep apnea, non-alcoholic fatty liver disease, and cancer (10) (9) (10) (81) (82) (83) (84). Other obesity related conditions include infertility and reproductive disorders, depression, and social stigmatization (81).

With an increasing obesity trend and relatively high prevalence among children, adolescents, and adults across sex, race, ethnicities, and socio-economic designations, researchers and policy makers have recognized obesity as a major public health problem (11). A contributing factor to the obesity epidemic has been an "obesogenic" environment that encourages high calorie food consumption (85) (86). Thus, an

environment that promotes healthy food access and eating habits is vital in combating obesity.

To date, diet quality has been shown to be significantly associated with obesity. For example, the USDA Economic Research Service (ERS) has examined the association between fruit and vegetable consumption and obesity and found a negative relationship between fruit and vegetable consumption and BMI (87).

Socio-Ecological Model

A socio-ecological approach has been recognized as a useful framework for integrating the numerous influences on food consumption both at the individual and environmental levels (14) (11) (88) (17) (16) (18) (19). Social ecological theory suggests that individual health decisions and behaviors are determined by multiple levels of influence, including institutional, community, and broader physical, economic, and cultural environmental levels (88).Thus, recent attention to the contribution of built environments to obesity ("obesogenic environments") has led to the development of several frameworks for empirically describing food environments with respect to the availability, accessibility, and pricing of foods associated with healthy eating behaviors (17) (16) (18) (19). As illustrated by Story and colleagues (2008) an ecological framework depicting multiple influence on what people eat demonstrates the complexity and interplay of factors that contribute to the obesity epidemic. Story and colleagues outline the following: "Individual-level factors related to food choices and eating behaviors include cognitions, behaviors, and biological and demographic factors. Environmental context related to eating behaviors include social environments, physical

environments, and macro-level environments". These four broad levels of influence all interact, both directly and indirectly, to impact eating behaviors (14). In Figure 1, an adaptation of Story and colleagues' socio-ecological model is displayed. As presented, the availability and accessibility of food outlets (type and location) in an individual's neighborhood are a part of the 'Community and Physical Environments'. An individual's perceptions and demographic characteristics are considered 'Individual Factors'.

The Food Environment

The built nutritional environment, or simply the "food environment", has become a major focal point in environmental and health outcomes related studies. Typically, the food environment has been described in two categories: 1) retail outlets i.e. supermarkets, grocery stores, and convenience stores and 2) fast food and restaurants. In this section, the two categories are discussed.

Retail Food Outlets

Food environment research suggests that access to various types of retail food outlets and the physical availability of food products in local stores impacts food choices (13). Further, research has produced evidence that availability and access to retail food outlets may influence obesity risk (20) (21) (26) (27) (28) (29) (30) (31) (32) (33) (34) (72) (73) (74) (75) (27) (76) (77) (78) (79) (80). In a review by Larson and Story (2009), studies have focused mostly on supermarkets, grocery stores, and convenience stores (13). Non-traditional food outlet types have been less studied and include drug stores, dollar stores, and general merchandise stores (40) (22).

Supermarkets are defined as large stores offering a full-line of products and possibly the services of a deli and bakery (13). Relative to other food outlets, supermarkets tend to have the lowest prices and offer the greatest variety of high-quality products including fruits and vegetables and low fat products (89) (13) (90). Moreover, audit studies of food stores tend to find that, compared with other retailers; supermarkets provide access to healthy food in greater variety and of higher quality (91) (92) (90); thus, access to supermarkets has become a commonly used measuring guide of the quality of the food environment. As for grocery stores and convenience stores, stock dry and canned goods and nonfood items are typically offered in grocery stores, with fewer perishable products than supermarkets. Convenience stores typically have limited shelf space, selections of staple groceries, ready-to-eat foods, and nonfood items, and little or no produce (13) (93).

Most studies have shown positive associations between supermarket access and healthier diets (13) (20) (21) (32) (94) (46) (50). Specifically, studies have shown that better access to supermarket shopping is associated with improved diet quality as it relates to fruit, vegetables, grains, folate, iron, and calcium (13) (50) (32) (94). In contrast, access to conveniences stores, which mostly contain high-calorie foods and little or no produce, has shown negative associations with diet quality, i.e. less fruit and vegetable consumption (95).

As for non-traditional food outlet types, a national report indicates that the market share of nontraditional outlets has increased from 17.4% in 1994 to 31.6% in 2005 (96) (22). Moreover, “dollar stores are emerging as important sources of food for many Americans looking to stretch their dollar, and the proliferation of drug stores is in part a

retail strategy to appeal to convenience with 4.8% of all food sales occurring in drug stores in 2005" (96). Given these findings, researchers should begin to incorporate these food outlets types into food environment research.

Fast Food and Restaurants

Fast food outlets and restaurants provide diverse food options for individuals with the research suggesting that the availability and accessibility to these food outlet types has a profound impact on food choices and obesity risk (20) (13) (97). Most research studies have broadly categorized restaurants as either limited-service or full-service restaurants. Limited-service restaurants are typically defined to include quick-service and fast-food establishments that prepare bulk amounts of food in advance and have customers pick up and pay for their food order at a counter before eating (13) (98). In contrast, full-service restaurants are characterized by having wait staff deliver customers' orders to their table (13). In a study by Lee and colleagues (2010), carry-out restaurants offered the lowest availability of healthy food choices (99).

In this realm, researchers have found that individuals that frequently eat at fast food restaurants have a less healthful and higher-calorie diet and increased risk of obesity (100) (101) (102) (103) (104) (105) (106) (107) (23). Moreover, these studies have found that frequent use of fast food restaurants is related to diets low in fruits and vegetables, diary, and many key micronutrients. Additionally, eating fast food has been linked to weight gain and diabetes (100). However, studies have found mixed results when relating fast food restaurant availability, diet quality, and weight status (108) (77) (23) (109) (46) (78) (110) (80). Thus, many studies have found that neighborhood access to a

fast food restaurant has no significant association with dietary intake. As for full-service restaurants, some evidence has suggested that individuals that frequent these establishments have healthier diets and lower levels of obesity (26) (110) (80) (23).

Individual and Neighborhood-Level Characteristics and Food Access

The relationship between the food environment and individual and neighborhood-level social characteristics can be discussed on multiple tiers including demographic (i.e. age and race/ethnicity), socio-economic (factors such as income and education), and by level of urbanization (urban versus rural communities). A growing body of evidence indicates differences by these tiers contribute to many disparities in food availability, access, and consumption in the United States (20).

In the realm of neighborhood differences and availability of food, a recent review by Larson and colleagues (2009) sought to describe research relating to neighborhood characteristics and food access (20). Larson and colleagues found that many studies have shown that residents in rural, low income, and minority communities are most often affected by poor access to supermarkets, chain grocery stores, and healthful food products (20). However, inconsistencies exist in some studies when comparing rural and urban communities. Thus, the food environment can affect outcomes in both urban and rural areas, but the causes and consequences within each may be different.

In another review, Michimi and Wimberly (2010) echo similar findings pointing out that impoverished neighborhoods, predominantly consisting of minority groups, are typically further away from supermarkets and quality, healthy food products when compared to wealthier, predominantly White neighborhoods in large metropolitan areas

and urban counties in many studies (111). Michimi and Wimberly conclude that in the literature, differences in access to food retailers that carry healthy food are often due to socioeconomic status and residential location and in rural communities the types of food outlets available and the range of healthy foods offered can vary greatly (111).

Given the many studies published, researchers have defined food environments with limited access to healthy and affordable food as "food deserts" (21) (24) (25). This term was originated in the early 1990s by Cummins and Macintyre (2002) where the authors defined food deserts as "poor urban areas, where residents could not buy affordable, healthy food" (112). This definition focuses on the type and quality of foods rather than the number, type and size of the food stores available to residents; however, since then, the phrase has been used differently by different researchers (25). In yet another review, Beaulac and colleagues (2009), state that most studies of food deserts commonly assess differential accessibility to healthy and affordable food between socioeconomically advantaged and disadvantaged areas (24). For example, the CDC has recently developed policy-level measures to study disparities in food access (113) (37).

Like neighborhood-level characteristics, individual-level factors regarding demographics and socioeconomic status, such as income and transportation, are important to be considered in food environment research. Although, many studies have involved neighborhood-level measures to illustrate disparities in food availability and access, the use of individual-level measures provides substantial context when examining utilization of the food environment. For example, the United States Department of Agriculture (USDA) reports that 'access' to a supermarket or large grocery store is only a problem for a small percentage of U.S. households, but urban core areas with limited

food access are characterized by greater racial segregation and income inequality. In small-town and rural areas with limited food options, the lack of transportation infrastructure is the most defining characteristic for individuals (21).

Defining the Food Environment: Neighborhood Boundaries

One challenge in measuring the food environment is determining the appropriate boundaries in which to define an individual's neighborhood, specifically, the geographic space in which an individual may travel to obtain food.

In recent reviews, the environmental features of residential neighborhoods have been defined either by the surrounding administrative unit (e.g., census tract, block group, or ZIP code) in most studies and as a "buffer" (e.g. 0.5 or 1 mile radius) in the remaining studies (114) (115) (116) . Moreover, "neighborhood" can have different connotations depending on an individual's interpretation (117). Given these discrepancies in defining neighborhood, a few studies have tried to examine these differences in the field of physical activity (66) (117). For example, in a study examining individuals' walking neighborhood boundaries Smith and colleagues (2010) found that adults' interpretation of their neighborhood area does not appear to relate accurately to the definitions typically used in research into environmental perceptions and walking. The researchers concluded that further investigation of the definitions used in existing measures may be warranted (66).

Recently the use of GIS technology and data has made it possible to construct measures of "neighborhood" or the local food environment that can be individualized to a specific home, worksite, school, or other community address (i.e. activity space) via

straight-line or network buffers around these locations (118). A buffer consists of defining a zone around a given location within a specified distance or shape. The location can be a point (home, school, work, or food outlet address), a line (street or road), or a polygon (neighborhood) (42). Most studies define buffers in order to quantify the availability or accessibility of food outlets. In the literature, buffers have been used around a respondent's home (89) (119) (32) (95) (78) (8), around a school (120) (121), and around food stores (122) (92), and around the centroid (geometric center) of each neighborhood (123) (124) (125) (126). Typically, a one-mile buffer around an individual's home has been accepted as a definition of neighborhood (115).

Measuring the Food Environment

Different methodological procedures have been used to characterize the food environment. These methods, both objective and subjective, have been used to assess variables related to the presence, quality, and proximity to food options and food outlet types in individuals' neighborhood food environments (42) (118) (67). In a review by Charreire and colleagues (2010), objective methods are the most frequently used to assess the food environment and to date have generally involved geographic information systems (GIS) (42). Additional objective measures include store audits (16) (97) and market baskets which aim to provide descriptive information on the pricing and quality of foods in retail stores and the food environment (67). Subjective methods include surveys of individual perception of the food environment including availability and accessibility to food options (94) (127) (42).

Objective GIS measures of the food environment can be discussed in terms of availability and accessibility. Availability is typically defined in food environment research as the physical location or presence of food retail outlets in a defined area (42) (43) (44). It is also used as a term to describe the presence of healthier foods within stores (67). Accessibility has been defined as the ease of access to available food options and outlets taking into consideration factors such as travel distance, time, and/or financial resources (43). However, the terms availability and accessibility are frequently used interchangeably.

Geographical Integrated Systems (GIS) Measures of the Food Environment

GIS are computer-based methods which by using different information sources, enable spatial and other data formats to be organized, managed and combined. They result in output that can be analyzed according to a geographic location (42). Analyses can then be carried out to model potential interactions between the different types of information at hand. In public health, examples of the use of GIS methods include the analysis of disparities in access to healthcare and, more recently, the association between the built environment and physical activity and nutrition (42).

Accessibility has been defined in GIS analyses by several measures including: 1) cumulative opportunity measures, 2) gravity based measures, and 3) random utility-based measures (43). Cumulative opportunity measures are a count of food outlets within a given area assigning less weight to food outlets further away (43). Gravity measures involve weighting measures by some factors such as size of food outlet or employee number and random utility-based measures uses the probability of an individual making a

decision to utilize a food outlet based on attributes assigned to that choice relative to all choices (43). Besides these measures, simple proximity or distance to nearest food outlet type has also been used as a form of accessibility (42) (115) (43) (125) (122) . Proximity can be measured by a straightline (Euclidean distance) or by travel time (time needed to travel to a food outlet).

Availability is a simple measure, and is typically the density or presence of food outlets or resources in a particular defined geographic area (43). Density has been typically defined by administrative areas (i.e. Census tract or ZIP codes) or an area defined by the researchers (i.e. buffer) (43).

Perceptions of the Food Environment

A major challenge in food environment research is the need for valid and reliable measures (13) (30) (41). Geographic information systems (GIS) have been the most common approaches for assessing local food environments (30) (41) (50). The use of GIS technology has allowed researchers to determine and map the presence of food outlets in an individual's environment and develop measures, however, "the presence of a food store may not necessarily translate into enhanced perceptions of food access, especially if the quality of the food in the store is less than ideal" (41).

Recently, surveys have increasingly been used to characterize the food environment (128) (129) (130) (50) (30) (131) (132) by obtaining information on residents' perceptions of the availability of healthy food items in their neighborhood (50) (30) as well as information on perceived presence of food outlets (45). Given this increased use of perception-based measures, researchers such as Moore and colleagues

(2008) stress the importance of understanding the relationship between perception measures and GIS-based measures of the local food environment. Ultimately, this will lead to improving measurement instruments, understanding of the influence of the food environment, interpretation of food environment related studies (50).

Perception-based measures have already been explored in the field of physical activity and the built environment with more than 100 published studies (133) (134) (135). The "environment" in these studies includes a combination of the physical (built) environment, social factors, and policy influences (135). To date, a many studies have made efforts to assess perceptions of the food environment (50) (30) (41) (54) (49) (55) (56) (52) (47) (57) (53) (53) (45) (48) (136) (137) (138) (139).

The most notable study by Moore and colleagues (2008) developed a three-item instrument to assess perceived availability of healthy foods within a 1 mile radius (or 20 minute walk) of participants' residence (50). This study found that participants living in areas of low supermarket density rated their perceived availability of healthy foods lower (17%) than those living in areas with the highest densities of supermarkets (50). Moore et al. also found that perceived availability to healthy foods was lowest for Non-Hispanic Black and low-income participants. Other published analyses by Moore and colleagues have also linked perceived and actual measures of the food environment to dietary intake. Moore et al. have reported that individuals without supermarkets near their homes are less likely to have a healthy diet than those with many stores, after adjusting for age, sex, race/ethnicity, and socioeconomic indicators (30).

In 2009, Freedman and Bell developed a healthful foods scale which consisted of an eight-item inventory that asked participants to rate food stores in their neighborhood

according to a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The inventory focused on access to healthful foods, access to alcohol and tobacco, and the quality and value of the neighborhood food stores. An overall measure of participants' perceptions of access to healthful foods was calculated using all eight items in the inventory (Cronbach's $\alpha = 0.64$, N = 37). Due to a low level of internal consistency yield from an initial composite, ultimately, a subset of four items was retained and included in the overall perceptions of access to healthful food scales (Cronbach's $\alpha = 0.80$, N = 37). Freedman and Bell found that participants' perceptions of access to healthful foods mirrored the reality of their food environments; however, perceptions of access to alcohol and tobacco were was not as accurate. Limitations of this study include the use of a small, nonrandom sample thus limiting the external generalizability of the findings. Similarly to other food environment studies, a 1 mile radius about a participants' residence was used to define and capture access to food. However, the authors pointed out that they did not know if the boundaries match the boundaries that participants used to define their local food environment (41).

In rural seniors (60 – 90 years) from the 2006 Brazos Valley Health Assessment, Sharkey and colleagues have used both objective and perceived measures of food store access and found that increased distance to the nearest supermarket, food store with a good variety of fresh and processed fruit, or food store with a good variety of fresh and processed vegetables were associated with decreased daily consumption of fruit, vegetables, and combined fruit and vegetables, after controlling for the influence of individual characteristics and perceptions of community and home food resources (52).

Another study by Gustafson and colleagues (2011) sought to highlight the similarities and differences between perceived and objective measures of the food store environment among 168 low-income women in North Carolina and the association with diet and weight. Overall, the study presented conflicting results when comparing subjective and objective measures at the store and neighborhood levels, while pointing to an association between objective (but not subjective) food store environment measures with weight and fruit and vegetable intake. In addition, Gustafson found that individuals who lived in census tracts with a convenience store and a supercentre had higher odds of perceiving their neighborhood high in availability of healthy foods (OR = 6.87 (95% CI 2.61, 18.01)) than individuals with no store.

In 2004, Garasky and colleagues found that rural clients were more likely than urban or suburban to perceive their food environment as having an inadequate number of supermarkets (50% compared to 22% and 13%, respectively). In addition, suburban clients' perceived local food as being more affordable compared to urban and rural clients; however, transportation concerns were the greatest among suburban and rural clients. In an Australian study by Giskes and colleagues, perceptions of food price and availability, rather than actual (objective) measures of the local food environment, were significantly associated with food-purchasing patterns (49).

A non-profit organization, The Food Trust, in Philadelphia has conducted work to investigate food access and disparities in which they included a perception of grocery quality in their field work (48). They found that nearly 228,000 residents believe that the quality of the groceries available in their neighborhood is fair or poor. Moreover, one in three poor adults in Philadelphia, representing 66,700 residents, report having fair or poor

quality groceries in their neighborhoods compared to 17.8% of non-poor adults. Also, black adults (31%) were more likely to report having fair or poor quality groceries in their neighborhoods compared to Latino (24%), Asian (15%), and White (11%) adults. Overall, adults in fair or poor health were nearly twice as likely to report a poor quality of groceries compared to adults in good or excellent health (15% vs. 7.5%).

In 2008, Inglis and colleagues was one of the first to examine the contribution of perceptions of food availability, accessibility, and affordability as a potential mediator for socioeconomic differences in fruit, vegetable, and fast food consumption finding that when considering perceptions, the association between socioeconomic variables and diet were not as significant or not significant at all (136).

In one of the first studies using multilevel regression analysis to examine factors that may affect individual perceptions of the neighborhood food environment, Zenk and colleagues (2009) found that satisfaction with neighborhood availability of fresh fruits and vegetables was lower in neighborhoods with greater concentration of African-American residents, but was not associated with neighborhood poverty (138). Additionally, Zenk found that living farther away from a supermarket was associated with lower satisfaction and individual education level modified the relationships between neighborhood availability of smaller food stores (small grocery stores and convenience stores) and neighborhood fresh fruits and vegetable satisfaction (138).

Lastly, Williams and colleagues in 2011 published findings on the congruency between the perceived and objective food environment showing that there is poor matching between what is availability in a person's neighborhood compared to their perception in a survey of 1,393 women in Australia (45). Food outlets included in their

analyses were supermarkets, 'fruit and vegetable stores', and fast food stores. In addition, Williams and colleagues found that socioeconomic disadvantage had little impact on the relationship between the perceived and objective food environment (45).

Bridging the Gap Between the Perceived and Actual Food Environment

Though limited in number and quality, perceptions studies have been able to show that there is a positive association between supermarket availability and perceived availability of healthy foods (50); however, others have reported mixed and contrary findings (53). In addition, researchers have found poor agreement between perceived and actual presence of three food outlet types, but have not been able to fully account for the findings (45). No study has examined how the relationship between the actual, built and perceived food environment varies when using different geographical boundaries to define a person's neighborhood. Lastly, only one study has studied the fast food environment as it relates to fast food and dietary intake quality using a self-reported or perceived fast food availability measure (51).

Thus, additional research is needed to explain the association between the perception of healthy food options and different food outlet types and the actual food environment. This will contribute to the overall understanding of food outlet utilization and food consumption (See Figure 2).

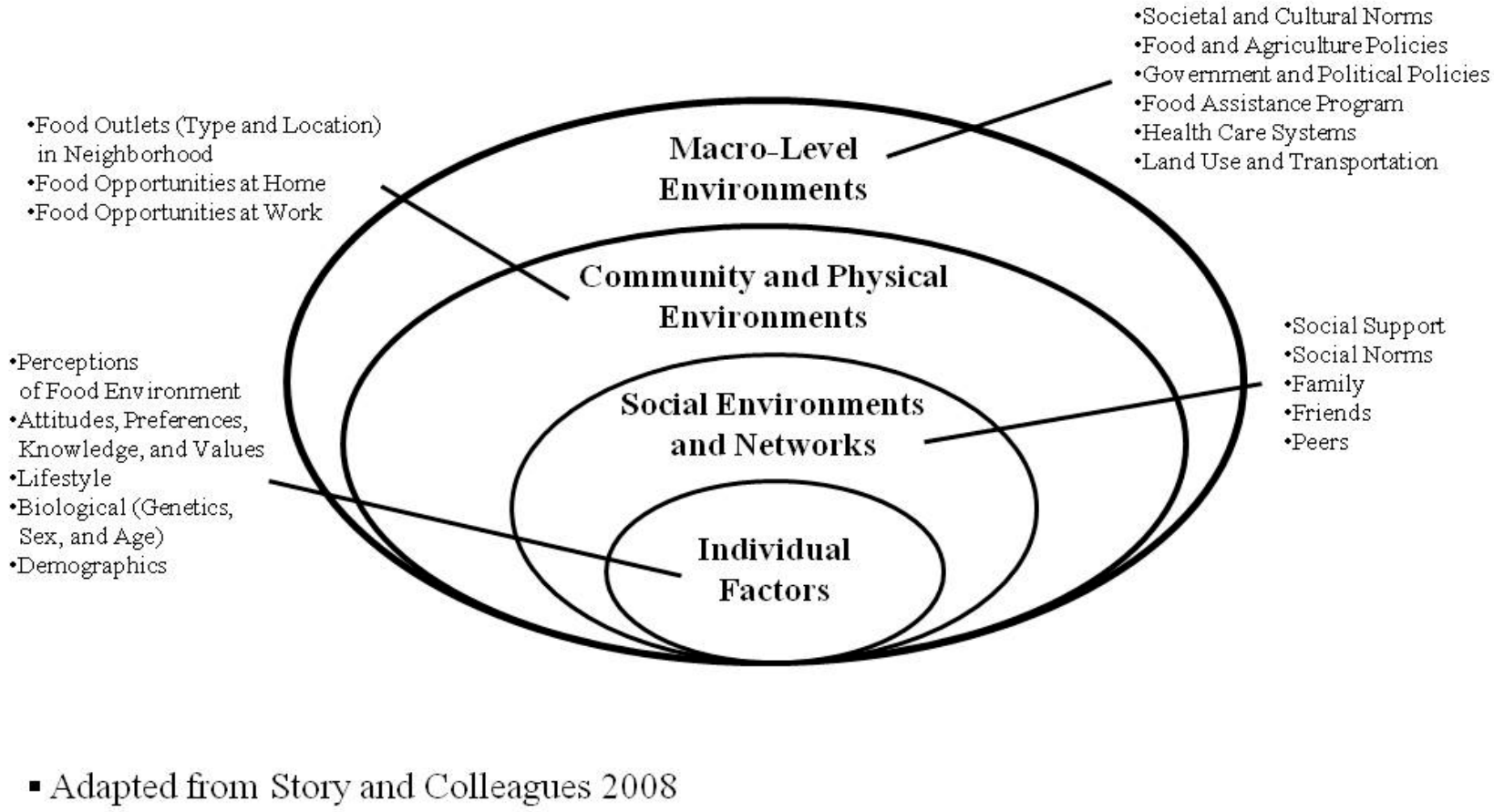

Figure 2.1. Socio-Ecological Model for Healthy Food Options and Individual Eating Behavior

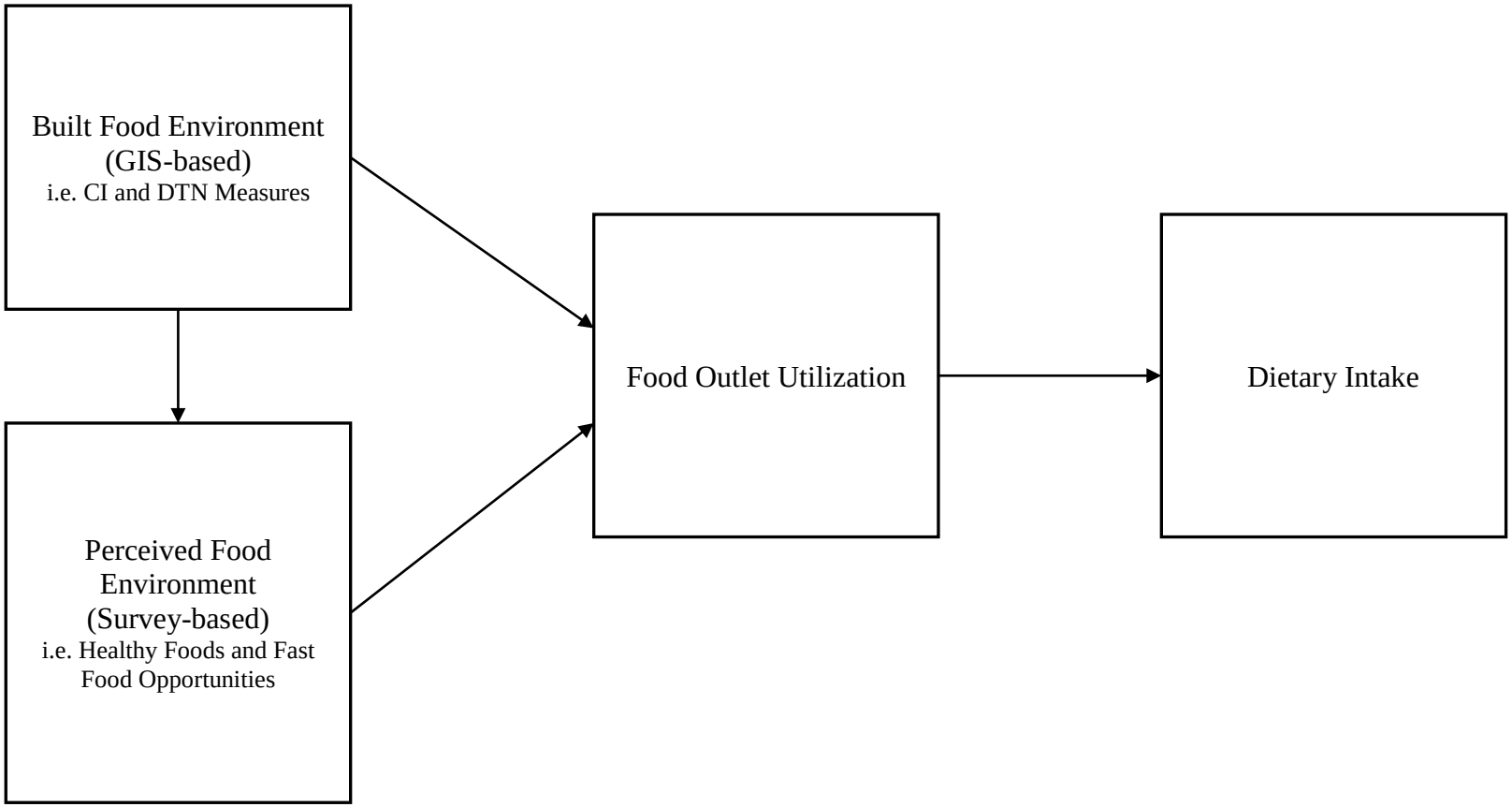

Figure 2.2. Conceptual Framework: Food Environment, Utilization, and Dietary Intake

CHAPTER 3

RESEARCH METHODS

Overview

The aims of this dissertation were to examine the association between the perceived and built neighborhood food environments in a sample of primary food shoppers in South Carolina. Understanding the relationship between individuals' perceptions and their actual food surroundings may provide insight into their actual food shopping behaviors, eating patterns, and, ultimately, their diet-related health outcomes including obesity. Further, the results of this work may provide a new perspective on how researchers should consider (or reconsider) food outlet location in public health nutrition research. To advance our understanding of this relationship, responses from a survey of 968 primary household food shoppers were utilized along with corresponding geographically ground-truthed, validated food outlet information within an eight-county region in South Carolina.

Data for the proposed aims originate from two previous projects, (1) an Eight-County Food Environment Study and (2) a Perceptions and Diet Study both funded under the Principal Investigator, Angela D. Liese, PhD, MPH, FAHA at the Center for Research in Nutrition and Health Disparities, Arnold School of Public Health, University of South Carolina.

The following sections will describe (1) the utilization of data from the two projects, (2) data linkage and management, and (3) data analyses.

Eight-County Food Environment Study

Funded by the National Institute of Health (NIH), the study entitled *"Developing Measures of Built Nutritional Environment"*, referred as the 'Eight-County Food Environment Study', (1R21CA132133-01) aimed to explore and quantify the nutritional environment. Specifically, the project systematically conceptualized and explored various food outlet availability and accessibility measures in a region spanning both rural and urban environments in South Carolina.

For this purpose, Dr. Liese and her research team established a spatially and temporally verified database comprised of 2,208 food outlets including the global positioning system (GPS) coordinates on all outlets. Thus, this study established a database representing the actual, built food environment on which these dissertation analyses were based. In addition, Dr. Liese's project has led to the development of a range of spatial measures of the community food environment using GIS.

Specific details of the study region, the food outlet data collection and management, and availability and accessibility measures developed in the Eight-County Food Environment Study are outlined in the following sections. Items discussed represent those facets of data which pertain directly to the aims of this dissertation.

Study Area

The study area consisted of a contiguous geographical area encompassing a total of eight counties (seven rural and one urban) in the Midlands region of the state of South Carolina (SC) (See Figure 1). The urban county, Richland, contains the state capital, Columbia, which is in the center in the middle of the state. The seven rural counties (Calhoun, Chester, Clarendon, Fairfield, Kershaw, Lancaster, and Orangeburg) comprise the rest of the study area. The study region covers 5,575 square miles (or 8,972 kilometers) and a population of more than 620,000 (15% of South Carolina's population), approximately half of whom are minority, primarily Black or African American, and spans a broad range of socioeconomic characteristics (140).

Establishing the Eight-County Food Environment

Constructing the spatially validated food environment database required several steps including: (1) obtaining a list of all possible food outlets in the eight-county study region, (2) field census i.e. groundtruthing and validation of all possible food outlets obtained, and (3) verifying the classification of all food outlet types. Data on food outlets in the study region were obtained from three secondary data sources, including the Licensed Food Services Facilities Database, from the SC Department of Health and Environmental Control (SCDHEC), Dun & Bradstreet, Inc. (D&B) and InfoUSA, Inc. D&B and InfoUSA listings were queried for specific North American Industry Classification System (NAICS) codes corresponding to facilities that sell food. A list of all facilities included are shown in Table 1. Each database was reviewed separately and duplicate entries (based on name and address) and outlets that were ineligible because of

geography or outlet type were removed. The databases were then merged by name and address into a single comprehensive database that listed each food outlet only once.

Next, a field census was conducted to verify the presence and location of each food outlet listed in the comprehensive database and to identify new, unlisted outlets. In addition, the GPS coordinates of each food outlet were recorded using a handheld device. Once the groundtruthing and field census work was complete, the accuracy of the food outlet type classifications was verified. To differentiate the types of food outlets, research staff first began by using the NAICS definitions as the basis of outlet type groups. For all listed food outlets, the NAICS codes were reviewed carefully by multiple team members and corrected manually as needed to remove obvious assignment errors. For all outlets that could not be assigned with certainty, team members conducted internet research and ultimately called the outlet to self-identify. For newly-discovered outlets, the type was assigned during groundtruthing. Specific and detailed methods of the groundtruthing and validation methods for establishing the Eight-County Food Environment are described thoroughly by Liese and colleagues (61) (141). The final distribution of open and availability food outlets in the eight county region is present in Figure 2.

Development of Availability and Accessibility Measures

GIS Software Utilization

Besides establishing the actual food locations, the Eight-County Food Environment Study explored availability and accessibility measures using ArcGIS software (Version 9.3, ESRI, Redlands, CA) and TIGER 2008 street and road network

data files (142). The ArcGIS software allowed for the construction of a spatially and temporally accurate and validated database of the food environment in which data, from a variety of sources, could be integrated and structured to conduct mapping activities and statistical analyses. These GIS data layers were used to create work maps for the groundtruthing effort, overlay the food outlet databases with road files to create assignments of food outlet location to Census tracts or block groups and facilitate computation of distances for the availability and accessibility measures

Food Environment Availability and Accessibility Measures

Development and application of availability and accessibility measures to the food environment database focused on two primary types of spatial measures: (1) cumulative indices and (2) proximity measures.

Cumulative Indices (CI)

The cumulative indices or CI is an availability measure and represents the number of food outlets in a specific spatial unit and is defined as the number of outlets of type j in the i^{th} unit as n_{ij}.

$$CI_{ij} = n_{ij}$$

The spatial unit can be any defined geography such as a U.S. census tract, block group, or in the case of this dissertation, road and street network buffers around a residential address. To date, this is the most frequently used measure being utilized in various built environment studies(33) (26) (27) (76) (77) (78,130) (41) (42) (115) (43). Simple derivatives of this index include density measures, either relative to population (93) (77)

(80) (143) or to area (126) (80). An underlying limitation of the CI is that the spatial unit defines the perimeter of a "neighborhood", i.e. constrains the availability measure to have a "local" nature.

Proximity or Distance to Nearest (DTN)

The distance to nearest (DTN) measure represents the closest food outlet determined by the shortest road and street network distance. It has been utilized in several studies related to the food environment (108) (144) (78) (145).

$$DTN_{ij} = \min|d_{ij}|$$

In these dissertation analyses, the groundtruthed, validated data was utilized to derive these two GIS-based availability and accessibility measures relative to participants' home (residential) addresses using various neighborhood defined network buffers.

Neighborhood Urbanicity

Analyses for the Eight-County Food Environment Study were conducted at the level of Census tracts and block groups. Census tracts cover, on average, a population of 4,000 individuals. The Census block group is the smallest geographical unit for which the Census bureau publishes data and is only collected from a fraction of households. In total, 150 Census tracts and 489 block groups lie within the eight-county study area. Each

spatial unit is classified individually with respect to level of urbanization (urban or non-urban) using the 2010 U.S. Census definition (63).

Perceptions and Diet Study

The Perceptions and Diet Study (3R21CA132133-02S1) addressed a set of aims supplemental to the Eight-County Food Environment Study. It specifically supported the addition of individual-level information to enhance Dr. Liese's evaluation of the GIS-based availability and accessibility measures by relating them to an individual's self-reported perception of their immediate environment including their food shopping behavior and dietary intake.

In order to accomplish the Perceptions and Diet Study, the following tasks were performed: (1) develop and pre-test survey on perceptions of the built (food) nutritional environment using focus groups and qualitative methods; and (2) conduct a telephone survey assessing the perceptions of the built nutritional environment, shopping behavior, and dietary intake among approximately 1,000 residents of the eight-county SC study region.

Details of the survey development and administration are outlined in the next few sections. In addition, the data collected from the telephone survey which relates to the proposed dissertation aims are described. These portions of the survey instrument include: (1) perceptions of the food environment and (2) the demographic characteristics.

Survey Development and Focus Groups

The survey development work included a phase of pilot testing and focus group-based refinement across urban and rural areas and racial and socio-economic groups. Specifically, there were 6 focus groups in which the research team developed and evaluated the survey instrument. Theoretical sampling involved recruiting focus group participants representing urban, suburban, and rural settings, with two groups in each. Each focus group included approximately 8 participants; Participants were recruited through community and social networks in each locale (e.g., through churches, health clinics, and community centers). The focus groups were semi-structured and provided an opportunity for participants to offer suggestions about the questions the research team were considering for use to assess perceptions of availability of healthy foods and other research components. It also allowed for crafting a survey that could be administered in a 15 to 20 minute timeframe.

Participants – Recruitment, Eligibility, and Enrollment into the Perceptions and Diet Study

Cross-sectionally designed, a geographically-based sample of approximately 1,000 adults who were the primary food shoppers of their household were recruited in the eight-county study region. Selection into the sample of households to participate in this study was done through random-digit dialing of landline telephone numbers (with listed addresses). Recruitment calls were made by the interviewing staff of the University of South Carolina (USC) Survey Research Laboratory (SRL). During the telephone calls, respondents were screened with respect to meeting the eligibility criteria including being

a) at least 18 years, b) the primary food shopper, c) capable of speaking English, and d) living in the eight county study area. Being the primary food shopper was determined by self report using a question (proxy) developed during survey development and focus group work.

As mentioned, the sample was restricted to households within the study region. This was accomplished by using a sample restricted to the 64 eligible ZIP codes of the eight-county study region with a goal of 15 respondents per ZIP code.

Survey Instrument

The final survey instrument consisted of six separate sections that included the following: (1) perceptions of the food environment, (2) primary and secondary food shopping behavior, (3) eating out behavior, (4) eating identity, (5) dietary behaviors, and (6) demographic characteristics. However, only the perceptions of the food environment and demographic characteristics are outlined in this section as these data directly address the dissertation aims.

Perceptions of the Food Environment

Perceptions of the food environment were ascertained and based on a previously validated instrument which has been applied in the MESA Neighborhood Study, a large-scale epidemiologic study (60). The purpose of the instrument was to measure the perceived availability of healthy foods within a person's neighborhood defined as 1 mile buffer or 20 minute walk. The properties of this instrument have been described and tested resulting in a Cronbach's α of 0.78 and a test-retest reliability measure of 0.69 (95% CI = 0.57, 0.77)(131). A Cronbach's α of 0.92 and a test-retest reliability measure

of 0.71 (95% CI = 0.60, 0.80) was determined in a sub-sample (n = 101) of participants in the Perceptions and Diet Study. Survey participants were asked to indicate the extent to which they agree with the following statements: (1) “A large selection of fruits and vegetables is available in my neighborhood”, (2) “the fresh fruits and vegetables in my neighborhood are of high quality”, and (3)”a large selection of low-fat products is available in my neighborhood”. The neighborhood considered was defined as a 1 mile buffer or 20 minute walk around a person’s home address. For analysis, each question was graded on a five-point Likert scale and aggregated into a summary score with 0 indicating worst availability of healthy foods and 12 indicating best availability. A separate question scored on a five-point Likert scale (Score Range 0 – 4) was asked to measure perception of fast food opportunities in a participant’s neighborhood. Specifically, the survey participants were asked to indicate the extent to which they agree with the following statement: “There are many opportunities to purchase fast foods in my neighborhood such as McDonald’s, Taco Bell, KFC and takeout pizza places etc”. This question had been previously tested for reliability with a κ (kappa) of 0.58 (95% CI = 0.39, 0.78) (60). The Perceptions and Diet Study data resulted in a test-retest reliability measure of 0.66 (0.54, 0.76).

In addition, information on the perceived presence (availability) of various food outlet types in each participant’s neighborhood, as a measure of awareness on the part of the resident was collected. Neighborhood was defined as a 1 mile buffer or 20 minute walk around the participant’s home. The food outlet types included supermarkets, supercenters, smaller grocery stores, convenience stores, freestanding drug and pharmacy stores, dollar and variety stores, specialty stores i.e. meat market, bakery, etc., franchised

fast food restaurants, and sit down restaurants. This question has not been previously utilized in the literature and was included in the Perceptions and Diet Study survey. In a sample (n = 101) of the Perceptions and Diet Study participants, these questions had a Spearman's correlation range of 0.67 to 0.98 and test-retest reliability measures ranging from 0.51 to 0.95. Supermarkets had a test-retest reliability of 0.77 (95% CI = 0.68, 0.84). Supermarkets had a Spearman's correlation of 0.77 and supercenters had a Spearman's correlation of 0.96. The perceptions questions are displayed in Figure 3. During questioning, interviewers emphasized participants to think of their neighborhood as an area within a 20 minute walk or 1 mile distance from home.

Individual Demographic and Socioeconomic Characteristics

A small number of questions on individual-level demographic and socio-economic characteristics were included on the survey. Characteristics included age, sex, race/ethnicity, height and weight, household income, level of education, marital status, participation in physical activity, diabetes status, transportation, home ownership, and number of individuals living in the home. These questions were based and taken directly from the established BRFSS survey (62). Survey respondents were also asked for their residential address for GIS purposes. In the Perception and Diet Study 70% of participants provided their address. Those unwilling were asked for the street names at the closest intersection. In the end, all addresses were accounted for either via the survey response or by using the street address included in the original telephone listing.

Data Linkage and Management

The survey data from each of the Perceptions and Diet Study respondent were assigned a unique identification (ID) number and geocoded to be linkable to geo-spatial data of the Eight-County Food Environment Study. The Eight-County Food Environment data include U.S. Census-based neighborhood-level characteristics i.e. level of urbanization.

Subsequently, GIS-based availability and accessibility measures were calculated using the participants' home address as the point of reference. These measures included the CI and DTN for the various food outlet types characterized in the Eight-County Food Environment Study and surveyed in the Perceptions and Diet Study. The food outlet types in which these two GIS-based measures were calculated include supermarkets, supercenters, grocery stores, warehouse clubs, convenience stores, drug and pharmacy stores, dollar and variety stores, and franchised limited service restaurants. In addition, GIS-based measures for a new aggregation of food outlet types were computed. This aggregation called "supermarkets" consisted of the sum of food outlets originally classified as 'supermarkets', 'supercenters', 'grocery stores', and 'warehouse clubs'. This variable is based on the notion that supermarkets, supercenters, and grocery stores typically represent those food outlets which provide access to healthy food in greater variety, higher quality, and affordability (91) (92); thus, access to these food outlets has become a commonly used criterion of the quality of the food environment. This classification has been previously used by CDC in their *2009 State Indicator Report on Fruits and Vegetables* (113).

The two GIS-based measures (CI and DTN) were calculated for the designated food outlet types at varying buffer sizes. These buffer sizes are based on road and street network buffers set at 1, 2, 3, and 5 miles centered on each participant's home address. In previous research, a 1 mile buffer size has typically defined an individual's neighborhood.

Final Dataset for Analyses

Variables of importance included those pertaining to perception-based measures (perceptions of the food environment survey questions), GIS-based derived variables (CI and DTN for each food outlet type varied by buffer size), individual-level demographic and socio-economic characteristics (Survey-based), and neighborhood-level urbanicity. The variables are described further in the next section. All data management were conducted in ArcInfo, Microsoft Excel, and SAS software version 9.2 (Cary, NC).

Definition of Variables

Perception-Based Measures

Perceived presence of different food outlet types is based on the participants' responses to the following survey question, "Which of the following stores, if any, are located in Your Neighborhood, that is within a 20 minute walk or 1 mile from your home?" (Figure 3) Nine individual food outlet types were included in the questionnaire resulting in 9 individual variables regarding perceived presence of a food outlet type in an individual's neighborhood. Specifically, the survey assessed the presence of a supercenter, supermarket, small grocery store, convenience store with or without a gas

station, specialty store (such as a meat market, seafood market, green grocer, or bakery), freestanding drug and pharmacy store, dollar and/or variety store, franchised fast food restaurant, and a sit down or buffet style restaurant. Each variable is coded dichotomously, categorized as either yes or no. In addition, a variable for aggregating food outlets originally classified as 'supermarkets', 'supercenters', 'grocery stores', and 'warehouse clubs' was created. It was also coded dichotomously, categorized as either yes or no.

The perceived availability of healthy foods score is calculated using the three questions developed and utilized previously by Echeverria and colleagues (60) and later Mujahid and colleagues (131). Survey participants were asked to indicate the extent to which they agree with the following statements: (1) A large selection of fruits and vegetables is available in my neighborhood, (2) the fresh fruits and vegetables in my neighborhood are of high quality, and (3) a large selection of low-fat products is available in my neighborhood. Each question is graded on a five-point Likert scale and aggregated into a summary score with 0 indicating worst availability of healthy foods and 12 indicating best availability.

The fast food perception score is based on a single, separate question and is also scored on a five-point Likert scale with 0 indicating worst availability and 4 indicating best availability. Specifically, the survey participants were asked to indicate the extent to which they agree with the following statement: "There are many opportunities to purchase fast foods in my neighborhood such as McDonald's, Taco Bell, KFC and takeout pizza places etc." (Figure 3)

GIS-Based Availability and Accessibility Measurement Variables

The actual presence of a food outlet type is based on the GIS verified food outlet database developed in the Eight-County Food Environment Study. For each participant, the actual presence of each of the nine food outlet types questioned in the perceptions survey as well as the created variable for "supermarkets" were determined using the home address of each individual as a point of reference and ArcGIS software. The presence of each food outlet type were determined at 1, 2, 3, and 5 mile road and street network buffer ranges. If a food outlet type is present, the corresponding variable was coded as yes; if not present, the variable was coded as no. This process resulted in 40 separate variables for each study participant related to the presence of each separate food outlet type at various buffer sizes.

The availability measure CI represents the count of a particular food outlet type within a given spatial unit or network buffer for each study participant. It is a continuous variable. For analysis, there were several CI measure variables calculated around each participant's home address. The food outlet types included in this group of variables include the aggregated variable for "supermarkets" in the Eight-County Food Environment Study and the Perceptions and Diet Survey as well as measures for convenience stores, drug and pharmacy stores, and dollar and variety stores, and franchised fast food outlets. In total, five different CI measure variables were determined for each study participant.

Distance to the nearest store (DTN) was calculated for the five food outlet types used for the CI variables. The DTN is a continuous variable calculated by using the

shortest road and street network distance to a particular food outlet type in ArcGIS. In total, five different DTN related variables were calculated for each study participant.

Individual Demographic and Socio-economic Factors

Age at time of survey is a continuous variable in years. Sex is a dichotomous variable, coded either male (=2) or female (=1). Race/ethnicity will be categorized as a dichotomous variable with a Non-Hispanic White group (=1) and a group categorized as Minority (consists of Non-Hispanic Black or African American, Hispanic, and/or other race/ethnicity) (=2).

Household income is a categorical variable and will be divided into four increments of income. Specifically, the categories are: (1) Less than $20,000 (reference group), (2) $20,000 or more. Education level is a variable categorized into three groups: (1) not a high school graduate, (2) high school graduate, no college, (3) some college and higher. Not a high school graduate will be the reference group. Spouse or partner status is a dichotomous variable, coded as yes or no. Employment status is a categorical variable grouped as employed (reference group), not employed, or retired. The number of individuals living in a participant's household is a continuous variable.

Neighborhood Urbanicity

Neighborhood urbanicity was assigned to each study participant using Census tract designation. Level of urbanization was classified individually with respect to level of

urbanicity using the a 2010 U.S. Census defined urban classification (63) via a point-in-polygon operation within ArcGIS.

Statistical Analyses Related to Dissertation Aims

Statistical analyses were conducted using SAS software version 9.3 (Cary, NC).

Specific Aim 1: Compare the perceived and GIS-based presence of various food outlet types (e.g. supermarkets, supercenters, small grocery stores, convenience stores, dollar and variety stores, drug stores and pharmacies, and fast food restaurants) in an individual's neighborhood food environment.

Research Question 1: To what extent does the perceived presence agree with the actual presence of the food outlet types using a standard 1 mile network buffer to define an individual's built neighborhood food environment?

Research Question 2: How does agreement change between the actual and perceived food outlet types' presence when varying the network buffer used to characterize the built neighborhood food environment? (Does the agreement change when using a larger, 2, 3, or 5, mile network buffer to define an individual's built neighborhood food environment?)

Statistical Approach for Aim 1:

To address the aim and related research questions, the concordance between perceived and actual presence as determined by GIS of food outlet types were

determined. Specifically, percent agreement, sensitivity, specificity, and positive predictive value (PPV) were calculated (See Figure 4). These agreement statistics are appropriate in situations that involve a binary classification test. Here, it is the perceived presence (or absence) of a food outlet type. Thus, the statistical procedure examines whether participants appropriately assigned or classified the possible outcome (i.e. perceived presence of a food outlet) compared to the actual or "correct" outcome (i.e. actual presence of a food outlet).

The initial agreement statistics were calculated using the standard 1 mile neighborhood definition. However, these statistics were also assessed comparing the perceived presence of a food outlet (at the 1 mile definition) compared to the actual presence at the 2, 3, and 5 mile neighborhood buffer sizes. This assessed if the 1 mile buffer size matched the boundaries that participants used to define their local food environment. It is possible that participants have overestimated the size of their neighborhood environment as defined in the survey and included food outlets not actually present within the 1 mile boundary.

In physical activity research, the use of different boundaries to define neighborhood has been examined (64) (65) (66). For example, Smith and colleagues have used in a physical activity related study mental maps and GIS measures finding that adults' interpretation of their neighborhood area does not appear to relate accurately to the definitions typically used in research (66). Additionally, studies such as in Colabianchi and colleagues (2007) and Boone-Heinonen et. al (2011) suggest researchers should address potential differences in relevant neighborhood areas across environmental features and population subgroups i.e. rural versus urban (64) (65).

95% Confidence Intervals (CIs) were calculated for these measures by approximating the binomial distribution with a normal distribution. In addition, categorical comparisons of these statistics were conducted by neighborhood urbanicity.

One hypothesis for this section of analyses included individuals would have a moderate (40 – 60%) agreement between the perceived and actual presence of food outlet types with supermarkets having the best agreement. Additionally, the agreement between individuals' perceived and actual presence of food outlet types would improve (increase) with increasing actual neighborhood buffer size.

Specific Aim 2: Examine the association between the perceived availability of healthy foods (fresh fruits and vegetables and low fat products) in an individual's neighborhood and the GIS-based availability and accessibility measures of specific food outlet types (e.g. supermarkets, supercenters, small grocery stores, convenience stores, dollar and variety stores, drug stores and pharmacies, and fast food restaurants) in an individual's neighborhood food environment. (Does the GIS-based food outlet type availability or accessibility predict or influence the perceived availability of healthy food options?)

Research Question 3: Is perceived availability of healthy foods (fresh fruits and vegetables and low fat products) in an individual's neighborhood associated with the GIS-based availability and accessibility measures of healthier food outlet types (supermarkets, supercenters, and small grocery stores) in an individual's neighborhood food environment?

Research Question 4: Is the availability and accessibility of less healthy food outlet types (convenience stores, dollar and variety stores, drug stores and pharmacies, and fast food restaurants) associated with the perceived availability of healthy foods?

Research Question 5: How do the association between GIS-based availability and accessibility measures of healthier food outlet types and perceived availability of healthy foods change when controlling for less healthier food outlet types?

Statistical Approach for Aim 2:

The statistical approach for aim 2 involved a series of linear regression models in which the dependent variable or outcome was the perceived availability of healthy foods. The independent variables consisted of the calculated availability and accessibility measures for food outlets i.e. CI and DTN measures. The analyses began from simple models consisting of availability of healthy foods score as the outcome and the availability and accessibility measures for supermarkets as the independent variable. As models progress, covariates related to demographic characteristics and level of urbanization were introduced into the models to assess any changes in association between the perceived availability of healthy foods and the GIS-based availability and accessibility measures.

In another step, a second series of models using availability and accessibility measures of the other food outlet types were also assessed in relationship to perceived availability of healthy foods. Lastly, GIS-based measures for all food outlet types including supermarkets were included final models.

A series of models are presented below:

Initial Models: Only Supermarkets

$\hat{y}$ = Perceived Availability of Healthy Foods Score = $b_0 + b_1 CI_{supemarkets}$

$\hat{y}$ = Perceived Availability of Healthy Foods Score = $b_0 + b_1 DTN_{supermarkets}$

Full Models: Only Supermarkets

$\hat{y}$ = Perceived Availability of Healthy Foods Score = $b_0 + b_1 CI_{supermarkets} + b_2 covariates$

$\hat{y}$ = Perceived Availability of Healthy Foods Score = $b_0 + b_1 DTN_{supermarkets} + b_2 covariates$

Covariates –Individual and Neighborhood Demographic and Socio-economic Characteristics

Full Models: All Food Outlets

$\hat{y}$ = Perceived Availability of Healthy Foods Score = $b_0 + b_1 CI_{supermarkets} + b_2 CI_{convenience} + b_3 CI_{drugpharmacy} + b_4 CI_{dollarvariety} + b_5 CI_{fastfood} + b_6 covariates$

$\hat{y}$ = Perceived Availability of Healthy Foods Score = $b_0 + b_1DTN_{supermarkets} + b_2DTN_{convenience} + b_3DTN_{drugpharmacy} + b_4DTN_{dollarvariety} + b_5DTN_{fastfood} + b_6covariates$

Covariates – Individual and Neighborhood Demographic and Socio-economic Characteristics

There were many hypotheses related to Aim 2. Primarily, it was hypothesized that there would be a positive association between the perception of healthy food options and the availability and accessibility of supermarkets. Conversely, there would be a negative association between the perception of healthy foods and the availability and accessibility of convenience stores, drug and pharmacies, dollar and variety, and fast food restaurants. Secondarily, individuals living in non-urban versus urban environments may differ in the associations between perceived and actual food environments.

By selecting linear regression (OLS – ordinary least squared), several classic assumptions had to be made. These assumptions include 1) linearity, 2) normality of the error distribution, 3) independence of the errors, 4) linear independence of predictors (no multicollinearity), 5) errors are uncorrelated, and 6) homoscedasticity (variance of the error is constant across observations). If these assumptions were violated during the course of analyses there were a few alternatives. In the case of multicollinearity, the removal of one or more variables would have been necessary or the addition of an interaction term. A nonlinear model could have also been necessary if the shape of the X-Y plot for an individual variable suggest an appropriate function to use, such as

polynomial or exponential. Transformations could have been applied to correct problems of non-normality or unequal variances. Removal of outliers or high-influence data points was assessed.

Specific Aim 3: Examine the association between the perceived availability of fast food opportunities in an individual's neighborhood and the GIS-based availability and accessibility measures of fast food restaurants in an individual's neighborhood food environment.

Research Question 6: Is perceived availability of fast food opportunities associated with GIS-based availability and accessibility measures of fast food restaurants in an individual's neighborhood food environment?

Research Question 7: How do the associations change when controlling for GIS-based availability and accessibility measures of other food outlet types?

Statistical Approach for Aim 3:

Like Aim 2, a series of linear regression models were utilized. In this aim we used the perceived availability of fast food opportunities as a dependent variable and the actual availability and accessibility fast food outlet measures as independent variables. Models are presented below:

Initial Models: Fast Food Outlets

$\hat{y}$ = Fast Food Perception Score = $b_0 + b_1 CI_{fastfood}$

$\hat{y}$ = Fast Food Perception Score = $b_0 + b_1 DTN_{fastfood}$

Full Models: Fast Food Outlets

$\hat{y}$ = Fast Food Perception Score = $b_0 + b_1 CI_{fastfood} + b_2 covariates$

$\hat{y}$ = Fast Food Perception Score = $b_0 + b_1 DTN_{fastfood} + b_2 covariates$

Covariates – Individual and Neighborhood Demographic and Socio-economic Characteristics

Full Models: All Food Outlets

$\hat{y}$ = Fast Food Perception Score = $b_0 + b_1 CI_{fastfood} + b_2 CI_{supermarkets} + b_3 CI_{convenience} + b_4 CI_{drugpharmacy} + b_5 CI_{dollarvariety} + b_6 covariates$

$\hat{y}$ = Fast Food Perception Score = $b_0 + b_1 DTN_{fastfood} + b_2 DTN_{supermarkets} + b_3 DTN_{convenience} + b_4 DTN_{drugpharmacy} + b_5 DTN_{dollarvariety} + b_6 covariates$

Covariates – Individual and Neighborhood Demographic and Socio-economic Characteristics

It was hypothesized that there would be a positive association between perceived availability of fast food opportunities and availability and accessibility of fast food restaurants. Urbanicity and GIS-based availability or accessibility of other food outlet types was possible significant factors that could influence the relationship.

Sample Size and Power

The Perceptions and Diet Survey collected data on a total of 968 participants. Power analyses were conducted prior to the study to determine the necessary sample size to detect a small effect (r = 0.10) with at least 80% power and alpha = 0.05. A sample of size of 900 was determined quite adequate. Thus, the current sample allowed us to detect correlations from .10 and larger.

Limitations and Concerns

Limitations of this dissertation included several methodological issues. First, there appears to be an apparent measurement error due to different resolutions of measurements and the need for assumption(s) when comparing the GIS-based food availability and accessibility measures with the Survey-based perception scores for healthy foods and fast food opportunity. Thus, the current analyses do not have data on the actually availability of fruits and vegetables and low fat products in each possible food outlet in our Eight-County study region. In the analyses, as supported by the current literature, the assumption was made that supercenters, supermarkets, grocery stores, and warehouse clubs are more likely to possess the highest availability and quality of fruits and vegetables compared to convenience stores, drug and pharmacy stores, dollar and

variety stores, and fast food. To date, this relationship has been accepted by several researchers (50) (51) (145) (45).

Another potential limitation with these analyses is that there is not an exact temporal match with the Eight-County Food Environment Study data and the Perceptions and Diet Survey data. Thus, the food environment and the survey administration occurred in slightly different time frames. For the Eight-County Food Environment Study, the data were collected between late 2008 and 2009. The Perceptions and Diet Study data were collected between April and June of 2010. Store counts could overestimate or underestimate the association due to new openings and missed closings of food outlets. Thus, if more stores are actually open then this could overestimate the agreement and association. If more stores are actually closed then this could underestimate associations. As a solution for this temporal mis-match the data was updated for the built food environment database with 2010 data from commercial datasets and the South Carolina Department of Health and Environmental Control (SC DHEC) for supermarkets. No significant differences in GIS-based measures were observed.

The sampling method for these data were based on a Zip code based method. However, the data collected are resolved to an individual's neighborhood level, so there is no need for hierarchical modeling. However, the telephone sampling approach was taken from landlines only which lead to an over-sampling of older adults.

Table 3.1. Description and Classification of Food Outlet Types

Food Outlet Type	Corresponding NAICS Codes
Retail Stores	
Supermarket	445110
Supercenter	452910
Grocery	445110, 452990, 453998
Warehouse Club	452910
Convenience Store	445120, 447110, 447190
Drug and Pharmacy	446110
Dollar and Variety	452112
Specialty (includes meat markets, seafood markets, green grocers, bakeries, and confectionary stores)	445210, 445220, 445230, 445291, 445292
Restaurants	
Full service restaurant (includes sit down restaurants, cafeterias, and buffets)	722110, 722212
Limited service restaurant (includes franchised and non-franchised fast food)	722211, 722213

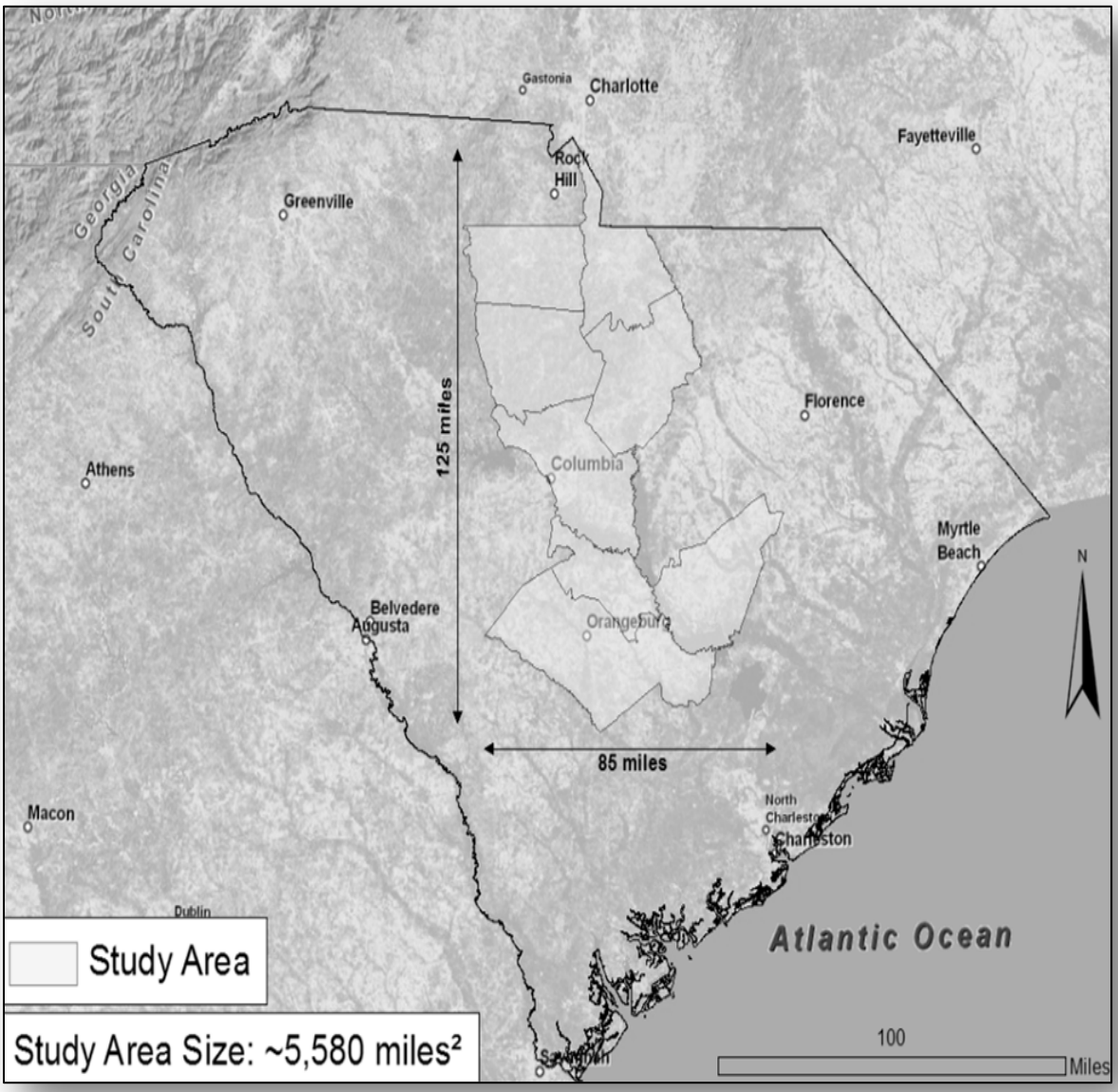

Figure 3.1. Eight-County Study Region

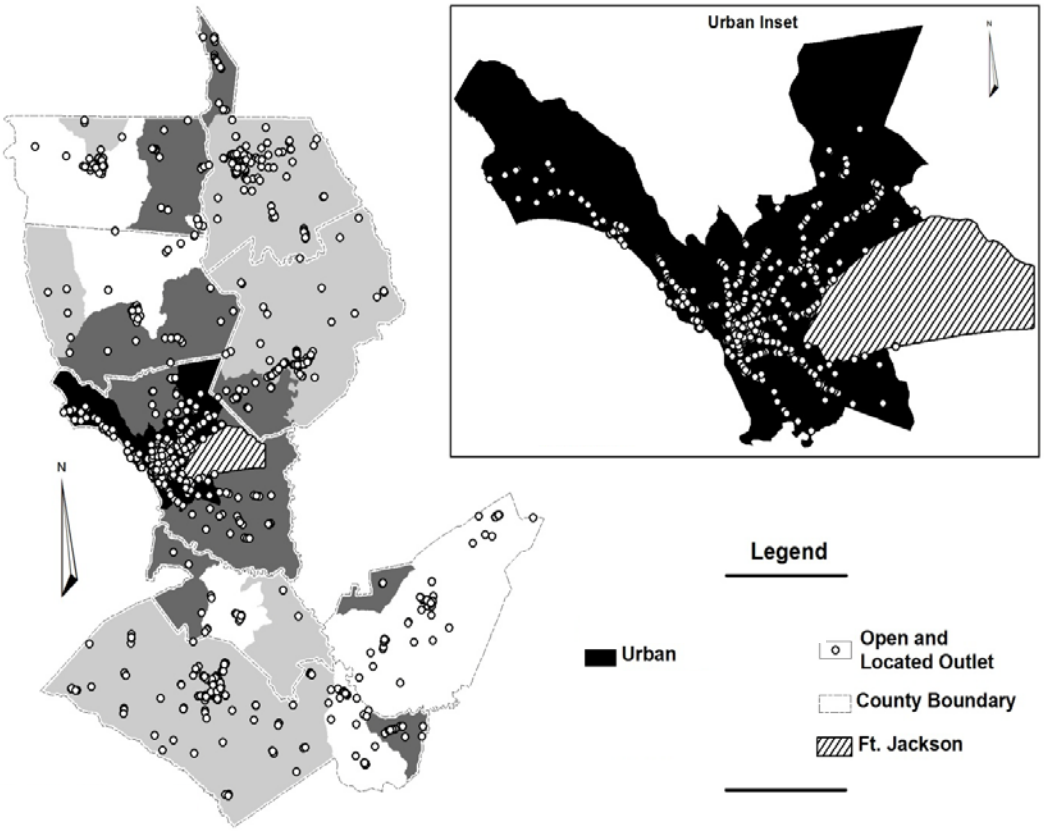

Figure 3.2. Open and Available Food outlets in the Eight-County Food Environment

For each of the following statements, please think of your neighborhood as the area within a 20 minute walk or about a mile from your home. Please indicate how much you agree with each of the following statements by choosing whether you strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree.
[Note to interviewer – emphasize that context is an area within a 20 minute walk or 1 mile from home. If responder responds with "I don't know" probe with "In general" or "Generally speaking",]

	1 Strongly Agree	2 Agree	3 Neutral Neither Agree nor Disagree	4 Disagree	5 Strong Disagree
Healthy Food Options					
1. A large selection of fresh fruits and vegetables is available in my neighborhood	□	□	□	□	□
2. The fresh fruits and vegetables in my neighborhood are of high quality	□	□	□	□	□
3. A large selection of low fat products are available in my neighborhood	□	□	□	□	□
Fast Food Opportunities					
1. There are many opportunities to purchase fast foods in my neighborhood such as McDonald's, Taco Bell, KFC, and take out pizza places etc.	□	□	□	□	□

Perceived Presence of Food Outlets		
Which of the following stores, if any, are located in Your Neighborhood, that is within a 20 minute walk or 1 mile from home?		
A Supercenter such as Wal-Mart or Target	□**Yes**	□**No**
A Supermarket such as Food Lion, Kroger, Publix, or Piggly Wiggly	□**Yes**	□**No**
A Smaller grocery store	□**Yes**	□**No**
Is a Convenience store with or without a gas station attached within a 20 minute walk or 1 mile from your home	□**Yes**	□**No**
A Specialty store such as ethnic specialty store, meat market, seafood market, green grocer, or bakeries	□**Yes**	□**No**
A Freestanding Drug store or Pharmacy such as CVS, Rite-Aid, Eckerd's or Walgreen's	□**Yes**	□**No**
A Dollar variety Dollar General, Dollar Store, Dollar Tree	□**Yes**	□**No**
Is a Franchised fast food restaurant including places like McDonalds, Subway, Taco Bell, within a 20 minute walk or 1 mile from your home	□**Yes**	□**No**
A Sit down restaurant or buffet restaurant	□**Yes**	□**No**

Figure 3.3. Perception of Neighborhood Food Environment Questions

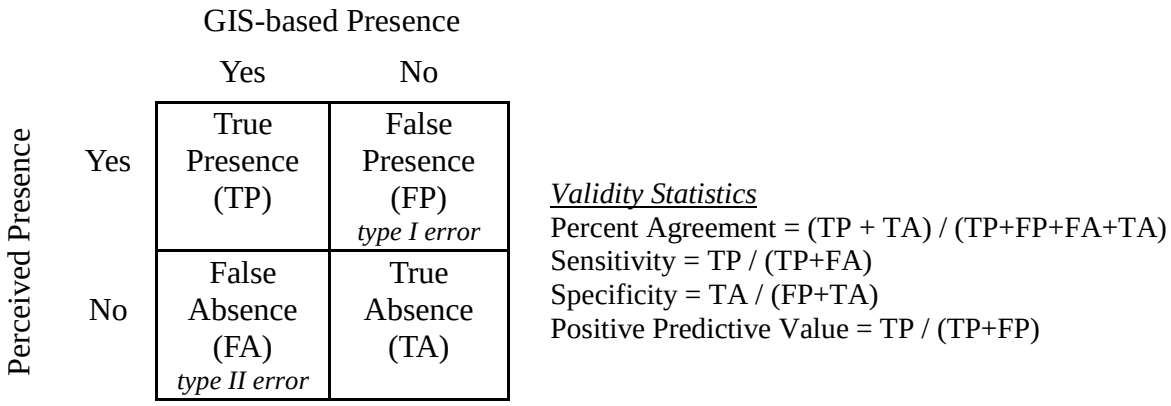

Figure 3.4. Aim 1 Analytic Approach Method

CHAPTER 4

MANUSCRIPT 1

Title: What's really in your neighborhood? Comparison of the perceived and GIS-based presence of retail food outlets

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Key words: Food Environment, Neighborhood, Perception, Presence

Abstract

Both objective and perceived measures of the food environment have been associated with dietary intake. However, few studies have examined the congruence between objective and perceived measures as they relate to the presence of a food outlet. Telephone survey data from 705 residents living in South Carolina were queried on perceived presence of food outlets within a 1-mile distance of their home. Geographic information systems (GIS) were used to determine the actual presence of food outlets within each resident's neighborhood using a 1-mile street network buffer. Validity statistics (i.e. percent agreement and sensitivity) were performed to assess the match between the perceived and GIS-based measures. Additionally, sensitivity analyses were conducted using varied GIS-based neighborhood buffer sizes (2, 3, and 5 miles) to examine changes in validity statistics. Residents' perceived their food environment quite accurately with percent agreements, present or not, for food outlets ranging from 67.1% to 83.5% using the 1 mile GIS-based neighborhood size. Sensitivities ranged from 82.3% to 92.5% with supermarkets and convenience stores having excellent values (92.5% and 90.1%, respectively). Increasing the GIS-based neighborhood size to 2 miles or higher significantly increased the validity statistic values and overall performance of respondents' perceptions. Validity statistics also differed significantly between urban and non-urban residents. Findings suggest that residents have an accurate awareness of their food environment. Additionally, the size and living in a non-urban neighborhood may affect the accuracy of their report. Future studies should consider testing larger neighborhood definitions to characterize perceived food environments.

Introduction

It has been suggested that the neighborhood food environment, whether measured objectively or subjectively, is associated with dietary intake (1). To date, geographic information systems (GIS) have been the most utilized objective method to characterize neighborhood food environments (2) (3) (4) (5). However, it is still not known whether GIS-based measures are the most appropriate means of defining an individual's food environment (1) (6) (7).

Perception measures based on surveys and self-report of respondents have increasingly been used to characterize the food environment (8) (9) (10) (11) (2) (6) (12). Moreover, perception measures have included residents' perceptions of the availability of healthy food items in their neighborhood (8) (9) (13) (14) (15) (16) (17) as well as information on perceived presence of different food retail outlets (14) (15) (16) (7). Presence is defined as the availability of a food outlet in a defined area (3) (4) (5). Several studies have shown that an individual's perceived availability and access to food outlets may also be related to diet and weight status (18) (18,19) (20) (7,21).

Most studies examining the perceived and GIS-based food environment have been descriptive in nature. A handful of studies have examined the relationship between perceived availability of healthy food choices, i.e. fruits and vegetables and low fat foods, and retail food outlet availability via GIS (9) (8) (14) (6). However, only a few studies have conducted analyses on the perceived presence of food retail outlets individually and whether resident survey responses are agreeable with a GIS-based measure (15) (16) (7). To the best of our knowledge, no study has assessed whether a self-report of presence of a food retail outlet could serve as proxy for an individual's actual food environment.

Characterizing the food environment via objective and GIS-based measures has many challenges including choosing appropriate food outlet data sources and the need for data validation (22) (23) (24). Therefore, if a measure of perceived food outlet availability were found to be valid, this may be beneficial in many food environment projects. Moreover, researchers and policy makers alike need to know whether people adequately perceive their current food environment and whether individuals' perceptions are adequate to detect changes in the food environment given neighborhood interventions and policy initiatives.

In addition, researchers need better ways to operationalize a person's environment or "neighborhood" (25). Many geographical boundaries have been used to define a person's GIS-based neighborhood, ranging from network buffer distances of 100m (26), 0.5 mile (27) (28) (29), 1 mile (30) (9) (8) and 2 miles (27) around their home address (1) (3). In addition, studies have measured the GIS-based presence of food outlets by U.S. census tracts and block groups (1) (3). However, in neighborhood perceptions' studies utilizing mental maps, researchers have found that residents' perceived neighborhoods can cover many different spaces and produce different boundaries (31) (32). Additionally, many factors such as age and gender (33), race (34), socio-economic class (35,36), and urban-suburban location (37) can affect residents' perceptions of their neighborhood environment. This is all information that should be considered when examining perceived and objective measures of neighborhood and the food environment.

This paper sought to provide an in-depth comparison of the perceived and GIS-based presence of food retail outlets in a sample of residents living in an eight-county region of South Carolina. Specifically we aimed to examine to what extent the perceived

presence agree with the actual presence of various retail food outlet types using a standard 1 mile buffer to define a resident's GIS-based neighborhood. Secondarily, we conducted sensitivity analyses by varying the defined GIS-based neighborhood utilizing 2, 3, and 5 mile buffers to examine whether the match significantly changed.

Methods

This is a cross-sectional, non-experimental research study utilizing responses from a survey consisting of 968 primary household food shoppers along with corresponding GIS-based measures of their food environment within an eight-county region in South Carolina. This is a supplemental analysis related to a larger research effort focused on developing measures of the built nutritional environment (22) (23) and examining perceptions, shopping behaviors, and diet in residents in the eight-county study region (38) (39). This study is approved by the University of South Carolina (USC) Institutional Review Board.

Study Region

The study area consisted of a contiguous geographical area encompassing a total of eight counties (seven non-urban and one urban) in the Midlands region of the state of South Carolina (SC). The urban county, Richland, contains the state capital, Columbia, which is center in the middle of the state. The seven non-urban counties (Calhoun, Chester, Clarendon, Fairfield, Kershaw, Lancaster, and Orangeburg) comprise the rest of the study area.

Study Participants

Recruitment of study participants was geographically-based and developed to achieve to achieve good spatial coverage of the entire study area. Specifically, selection was done through a random selection of landline telephone numbers with listed addresses restricted to 64 eligible ZIP codes within the study area with a goal of 15 respondents per ZIP code. Recruitment calls were made by the interviewing staff of the USC Survey Research Laboratory (SRL). Respondents were screened with respect to meeting the eligibility criteria including being a) at least 18 years, b) the primary food shopper, c) capable of speaking English, and d) living in the eight county study area. Of the 2,477 household telephone numbers screened, a total of 968 residents were eligible and completed the interview. However, there were 553 refusals, 377 ineligibles, and 579 of non-contact, unknown, or other status. Applying the American Association for Public Opinion Research Response Rate Formula 4 (40), we estimated a response rate of 47%, which is very comparable to the 49% among landline households achieved in a recent evaluation of the Behavioral Risk Factor Surveillance System landline response rates conducted in 18 US states (41).

Perception Measures

Perceived presence of a food retail outlet was obtained utilizing a set of newly developed and validated questions (Figure 1) (38). A person's neighborhood was defined as a 1 mile buffer or 20 minute walk around their home (9) (8). Response options were dichotomous, "yes" or "no". The list of food outlet types queried included supercenters, supermarkets, convenience stores, drug stores or pharmacies, dollar and

variety, and franchised fast food restaurants. In analyses, supermarkets and supercenters were aggregated based on the notion that supermarkets and supercenters typically represent those food outlets which provide access to healthy food in greater variety, higher quality, and affordability (42) (43). This classification has been previously used by Centers for Disease Control and Prevention (CDC) in their 2009 State Indicator Report on Fruits and Vegetables (44).

GIS-based Measures

GIS-based presence of food retail outlets was determined using each resident's home address as the point of reference with varying street network buffers (1, 2, 3, and 5 mile) representing their neighborhood boundaries. Dichotomous variables representing the presence ("yes" or "no") for all food outlet types were then created. Presence was determined using previously validated, linked geospatial data characterizing the food retail environment of the eight-county study area (22) (23). Residents' addresses were geocoded using ArcGIS 10.0 (ESRI, Redlands, CA 2010).

Resident Characteristics

The resident characteristics were based on the Behavioral Risk Factor Surveillance Survey (BRFSS) (45). Characteristics included age, sex, race/ethnicity, education, employment status, household income, utilization of the Supplemental Nutrition Assistance Program (SNAP), marital/partner status, and number of individuals living in the home. Each survey respondent was also classified individually with respect

to level of urbanicity, urban or non-urban, using the a 2010 U.S. Census defined urban classification via a point-in-polygon operation within ArcGIS (46).

Statistical Analyses

Perceived and GIS-based presence of food retail outlets were used to construct validity statistics including the overall percent agreement, sensitivity, specificity, and positive predictive value (PPV), using a standard 1 mile network buffer to define the GIS-based neighborhood presence. 95% Confidence Intervals (CIs) were calculated for these measures by approximating the binomial distribution with a normal distribution. In addition, we conducted sensitivity analyses by varying the defined GIS-based neighborhood buffer sizes (i.e. 2, 3, and 5 miles) to examine whether the validity statistics changed. Differences between validity statistics by buffer sizes were assessed using non-overlapping conference intervals. Thus, if confidence intervals for two statistics do not overlap then the values are significantly different.

Sensitivity was defined as the proportion of residents who perceived a food outlet type to be present when it was, in fact, present in the GIS defined neighborhood (i.e., present-present). Specificity, on the other hand, relates to the perceived absence of a food outlet type given a food outlet is absent in the GIS defined neighborhood (i.e., absent-absent). Percent agreement (PA) represents the proportion of residents that accurately perceived the presence or absence of a food outlet type in their corresponding GIS-based neighborhood food environment when there was an actual food outlet presence or absence, respectively. Positive predictive value (PPV) measured the proportion of residents who had a food outlet present in their GIS-based neighborhood

food environment and perceived that food outlet type present. For ease of discussion, validity statistics below 30% were consider poor, 31 – 50% as fair, 51 – 70% as moderate, 71 – 90% as good, and over 90% as excellent. This classification method has been used in several studies (47) (48).

Of the total 968 survey respondents, we removed those that were missing any perception measures (n=5) and resident characteristics (age, 71; race/ethnicity, 73; education, 69; employment status, 68; household income, 215; SNAP status, 69; spouse or partner, 64; number of household members, 74; urbanicity, 18), leaving 705 for analyses.

Results

The majority of residents were female (77.7%), Non-Hispanic White (65.5%), and lived in non-urban neighborhoods (77.5%) (Table 1). The mean age for all residents was nearly 57 years old. Eleven percent of residents did not have a high school diploma, 22.6% were unemployed, 28.9% had a household income less than $20,000 per year, and 9.9% of residents received SNAP benefits. Sixty-four percent of residents had a spouse or partner in the household and, on average, residents lived with 2.5 household members.

Using the standard 1 mile buffer to define the GIS-based neighborhood, 31.8% of residents indicated that they had a supermarket in their neighborhood compared to 11.3% of residents who actually had a supermarket in their neighborhood based on GIS (Table 2). Similar discrepancies were observed for convenience stores (55.7% vs. 28.5%), drug and pharmacy stores (28.9% vs. 13.9%), dollar and variety (39.4% vs. 14.8%), and

franchised fast food restaurants (26.8% vs. 16.0%). However, larger neighborhood buffer sizes (i.e. 2 and 3 miles) resulted in a larger number of food outlets being captured by the GIS-based definitions, and hence agreement between residents' perceptions and reality improved.

For virtually all outlet types, the vast majority (>80%) of residents who had a specific retail outlet situated within a mile from their home were aware of its presence as indicated by sensitivities ranging from 82.3% for fast food outlets to 90.1% for convenience stores to 92.5% for supermarkets (Table 2). Specificities, however, were more variable and ranged from 57.9% to 83.8%. However, PPVs were quite low ranging from 33% to 49.2%, indicating that only a third to one half of residents who had a food outlet present in their neighborhood actually reported an outlet to be present correctly in their assessment. Overall percent agreements for residents were a little lower, ranging from 67.1% for convenience stores to 83.5% for franchised fast food restaurants. When using the other GIS-based neighborhood buffer sizes, there was a statistically significant difference between sensitivity, specificity, and PPV values compared to the standard 1 mile buffer size. For supermarkets, sensitivity was significantly lower using the 3 and 5 mile buffer sizes (72.8% and 56.7%, respectively) compared to the 1 mile buffer sensitivity (92.5%). In contrast, specificity and PPV values for supermarkets significantly improved with an increase in buffer sizes. Generally, validity statistics for convenience stores, drug and pharmacy stores, dollar and variety, and franchised fast food also followed a similar pattern; as the GIS-based neighborhood buffer size increased, sensitivity values decreased and specificity and PPV values improved. However, there were no significant differences in percent agreement values for any outlet

type when comparing 2, 3, and 5 mile buffers to the 1 mile GIS-based neighborhood buffer size. The percent agreement among residents did peak using the 2 mile GIS-based neighborhood buffer size.

Validity statistics were also determined by stratifying residents by urban and non-urban classification. Sensitivity values for urban residents were significantly higher than non-urban residents for supermarkets, drug stores, fast food restaurants, using the 1 and 2 mile GIS-based neighborhood buffer sizes. Specificity and PPV values were also significantly different between urban and non-urban residents for nearly all food outlet types using the 1 mile GIS-based neighborhood buffer size. Specificity values were significantly higher in non-urban residents compared to urban residents while PPV values were significantly lower in non-urban residents compared to urban residents. However, there were no significant differences in values for overall percent agreement using either the 1 or 2 mile neighborhood buffer sizes, except for supermarkets using a 1 mile buffer size.

Discussion

In this study, residents perceived their food environment quite accurately with percent agreement for food outlets ranging from 67.1% to 83.5% using a standard 1 mile GIS-based neighborhood buffer size. Additionally, sensitivities ranged from 82.3% to 92.5% with supermarkets and convenience stores having the highest sensitivity values (92.5% and 90.1%, respectively). In sensitivity analyses using larger GIS-based neighborhood buffer sizes, specificity and PPV values significantly improved as sensitivity values decreased, indicating that individuals may be overestimating the size of

their neighborhood food environment, even if asked a question that specifically asked them to conceptualize their neighborhood perspective of 1 mile or 20 minute walk from their home. In addition, we found that urban and non-urban residents' overall percent agreement for food outlets did not differ significantly using either the 1 or 2 mile neighborhood buffer sizes. However, there were significant differences between other validity statistics especially when using the 1 mile neighborhood buffer size. Overall, it appears that using a larger 2 mile buffer to define neighborhood yielded the best validity statistics, which suggests that our survey question on presence of a food outlet likely covers a larger (i.e. 2-mile) area than its literal frame.

To best of our knowledge, only two studies have included analyses comparing perceived and GIS-based presence of food outlets directly (7,16). In a sample of 1393 women, aged 18 – 65 years, in Melbourne, Australia, Williams et al. found that the match between the perceived and objective food environment was quite poor, reporting approximately 50% of women had a complete agreement between their perceptions and objective measure of supermarket presence within 800m (~0.5 miles) of their home (16). For a fast food store, the match was only 40%. This outcome is much different than our study in which we had a good percent agreement for both supermarkets and fast food restaurants (77.9% and 83.5%, respectively). Possible discrepancies between our results and those of Williams et al. could lie in the nature of the perception question and the choice of GIS-based measure. In our study we specifically asked study participants to think of their neighborhood environment as a "1 mile buffer or 20 minute walk" around their home, while participants in the study by Williams et al. were asked the question "Are the following within walking distance of your home?" without any guide to

"walking distance". Moreover, Williams et al. in analyses classified participants as having or not having each store by using a 800m (~0.5 miles) definition as 'walkable distance'. In another study, Caspi et al. reported a mismatch of 31% between objectively and perceived presence of a supermarket within 1 kilometer (~0.6 miles) in a sample of low-income housing residents in three urban areas in the greater Boston area. Thus, only 69% of residents in their sample matched. Again, in our study we had an agreement of 77.9% using a 1 mile GIS-based buffer size and the match increased to 84.3% using the 2 mile GIS-based buffer size. This may suggest, that Caspi et al. used a buffer size too small to optimize concordance between a person's perceived and objectively measured food environment. Moreover, Caspi et al. increased their cut-point for a neighborhood buffer to 1 kilometer because the researchers were concerned about artificially high levels of discordance based on previous buffers used in the literature and since most of their participants reported a supermarket within walking distance (7). In our study area, the majority of food shoppers travel by car (>90%) and do not walk to food outlets, even in urban neighborhoods.

Our study contributes to food environment research by not only exploring the match between an individual's perceived and actual presence of supermarkets and other retail outlets, but also examining how the relationship changes using different boundaries to define a person's actual neighborhood. It could be the case in the Williams et al. and Caspi et al. studies, cut-points to define a person's neighborhood may affect agreement between perception and reality. In our study, we found that by increasing the GIS-based neighborhood definition to a 2 mile buffer size or higher significantly increased the validity statistics and overall performance of respondents' perceptions. Moreover, it

could be the case that residents overestimate the size of their neighborhood food environment. However, additional studies comparing both perception instruments that operationalize neighborhoods differently (i.e., 2 miles, 3 miles, etc.) and GIS-based measures are needed to address this phenomenon. Moreover, it is possible that residents are not able to mentally conceptualize what 1 mile buffer around their home based on personal and behavioral factors.

For over fifty years, researchers have been interested in individuals' perceptions of their neighborhood and corresponding boundaries. Recently, Coulton et al. have developed methodology of retrieving neighborhood residents' perceptions of neighborhood boundaries via mental maps to explore perceived neighborhood boundaries with Census (i.e. GIS-based) defined neighborhoods (31). In their study, they found that residents' perceived neighborhoods covered different spaces and produced different neighborhood boundaries compared to the Census-based neighborhoods. Overall, Coulton et al. found that the mean area of residents' maps were 0.32 square miles and had a perimeter of 2.24 miles. In our study, the mean neighborhood food environment of residents using the 1 mile neighborhood buffers size was 0.71 square miles with a mean perimeter of 7.75 miles. For the 2 mile buffer, the mean neighborhood food environment area was 2.81 square miles and a mean perimeter of 22 miles. Future studies should consider developing standardized neighborhood definitions based on methods that include residents defining their perceived neighborhood on a map or using other mapping techniques.

Our study has several limitations. First, women constituted the majority of the sample we selected the primary food shopper. This may limit the generalizability of our

findings. Second, our landline-based telephone sample yielded an age distribution with an average age in the middle-to-older age category, which does not represent all residents. Third, the perceptions data was collected nearly one year after the completion of the validated field census. However, this gap between data collection seems negligible compared to other studies (9) (14).

Strengths of the study included the use of a validated food environment instrument examining the perceived presence of food outlet types (38). Secondly, our GIS-based presence was based on a validated field census of our study region (22) (23). In addition, our study area contained both urban and non-urban communities, which included residents with different individual and neighborhood socio-demographic characteristics, such as income and education and neighborhood SES. Moreover, these findings may be beneficial and comparable to any new studies examining populations in the Southeastern United States where there is a mix of urban and non-urban neighborhoods. Studies by Williams et al. and Caspi et al. have both only examined residents living in urban communities.

GIS has been an important and useful tool for defining the food environment to individual's diet, weight status, and neighborhood characteristics; however, measures based on GIS may not be completely valid (22) (23) (24) (49). The effort to validate this information is often not feasible due to resources and the expense of research staff to travel into the field (49). In addition, there is not a gold standard for defining a person's neighborhood food environment (3). It may be cheaper and more accurate if perceptions measures are utilized, either alone or in tandem with GIS-based measurements (9) (7). Our study demonstrates there is a good match between what residents perceive in their

neighborhood compared to what is actually present, especially for supermarkets. However, our study also points out that there is still room to evaluate the appropriate neighborhood boundaries both for GIS-based measures and perception instruments.

Perceived Presence of Food Retail Outlets[*]

Which of the following stores, if any, are located in your neighborhood:

1. A supercenter such as Wal-Mart or Target
2. A supermarket such as Food Lion, Kroger, Publix, or Piggly Wiggly
3. A convenience store with or without a gas station attached
4. A freestanding drug store or pharmacy store such as CVS, Rite-Aid, Eckerd's, or Walgreen's
5. A dollar variety, dollar general, dollar store, or dollar tree
6. A franchised fast food restaurant including places like McDonald's, Subway, or Taco Bell

*Response options were simply "Yes" or "No"

Figure 4.1. Perceptions of the Food Environment Survey Questions

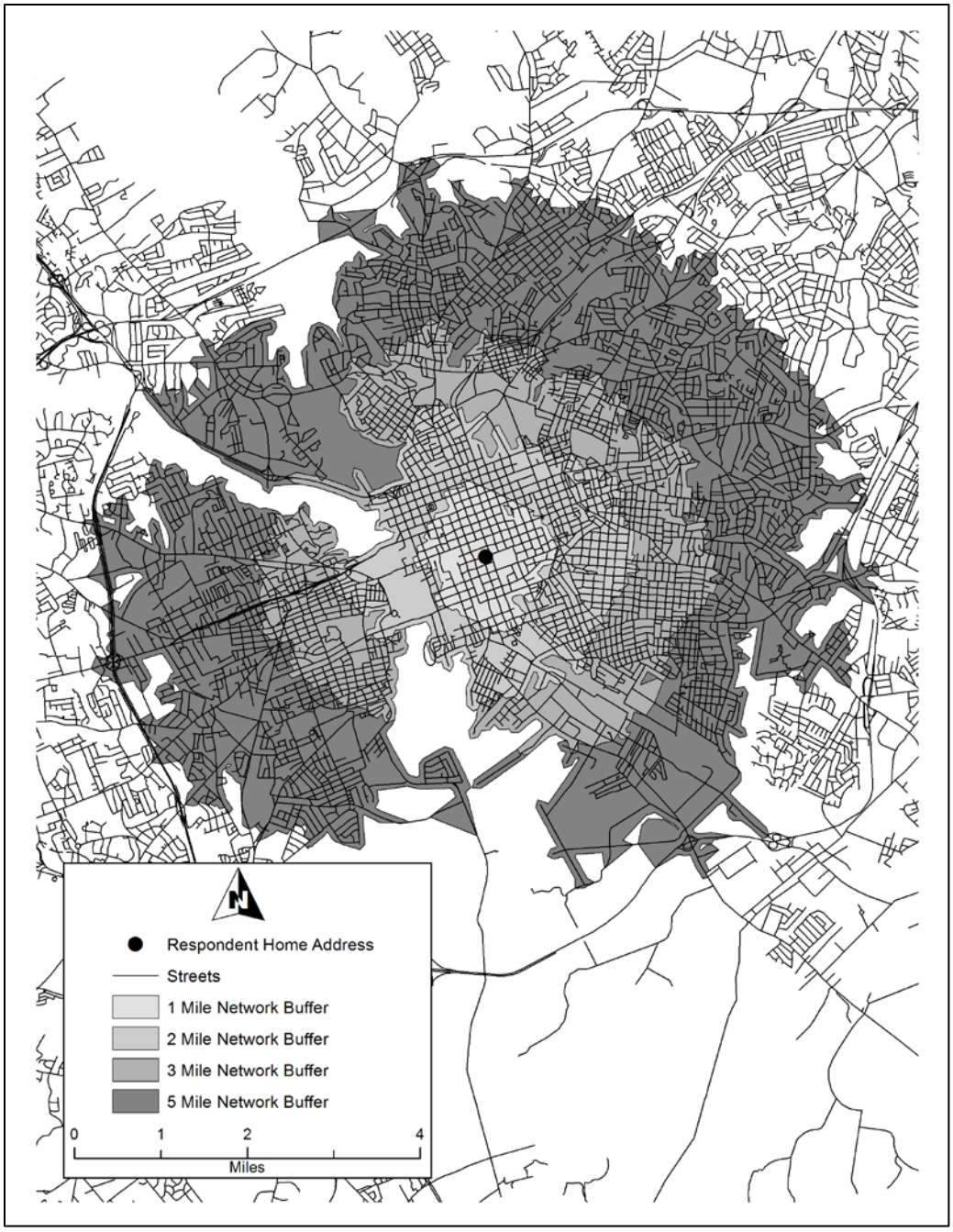

Figure 4.2. Example of a Resident's GIS-based Neighborhood Food Environment using 1, 2, 3, and 5 mile Buffer Sizes

Table 4.1. Descriptive Statistics of Residents' Characteristics, N=705

		n (%) or Mean (SD)
Age (years)		56.5 (14.7)
Gender	Male	157 (22.3)
	Female	548 (77.7)
Race/Ethnicity	Minority (Non-Hispanic Black, Hispanic, or Other)	243 (34.5)
	Non-Hispanic White	462 (65.5)
Education	< HS diploma or GED	80 (11.4)
	HS diploma or GED	251 (35.6)
	Some College or Higher	374 (53.1)
Employment Status	Not Employed	159 (22.6)
	Retired	222 (31.5)
	Employed	324 (46.0)
Household Income	< $20,000 per year	204 (28.9)
	≥ $20,000 per year	501 (71.1)
SNAP Status	No	635 (90.1)
	Yes	70 (9.9)
Spouse or Partner	No	253 (35.9)
	Yes	452 (64.1)
# of Household Members		2.5 (1.4)
Urbanicity	Non-Urban	558 (79.1)
	Urban	147 (20.9)

Table 4.2. Validity Statistics Between Perceived and GIS-based Presence of Food Retail Outlets By Varying Neighborhood Buffer Sizes, N=705

	Perceived Presence "Yes", n (%)	GIS-based Presence "Yes", n (%)	Sensitivity (95% CI)	Specificity (95% CI)	Positive Predictive Value (95% CI)	Percent Agreement (95% CI)
Supermarkets						
1 mile buffer	224 (31.8)	80 (11.3)	92.5 (86.7 – 98.3)	76.0 (72.7 – 79.3)	33.0 (26.8 – 39.3)	77.9 (72.3 – 83.4)
2 mile buffer	224 (31.8)	173 (24.5)	82.7 (77.0 – 88.3)	**84.8 (81.7 – 87.8)***	**63.8 (57.4 – 70.3)***	84.3 (79.4 – 89.1)
3 mile buffer	224 (31.8)	232 (32.9)	**72.8 (67.1 – 78.6)***	**88.4 (85.4 – 91.3)***	**75.4 (69.7 – 81.2)***	83.3 (78.3 – 88.3)
5 mile buffer	224 (31.8)	342 (48.5)	**56.7 (51.5 – 62.0)***	**91.7 (88.9 – 94.6)***	**86.6 (82.1 – 91.2)***	74.8 (68.9 – 80.6)
Convenience						
1 mile buffer	393 (55.7)	201 (28.5)	90.1 (85.9 – 94.2)	57.9 (53.6 – 62.2)	46.1 (41.0 – 51.1)	67.1 (62.4 – 71.8)
2 mile buffer	393 (55.7)	328 (46.5)	**79.9 (75.5 – 84.2)***	65.3 (60.4 – 70.1)	**66.7 (61.9 – 71.4)***	72.1 (67.5 – 76.6)
3 mile buffer	393 (55.7)	422 (60.0)	**71.6 (67.3 – 75.9)***	**67.8 (62.4 – 73.3)***	**76.8 (72.6 – 81.1)***	70.1 (65.5 – 74.7)
5 mile buffer	393 (55.7)	574 (81.4)	**59.9 (55.9 – 63.9)***	62.6 (54.3 – 70.9)	**87.5 (84.2 – 90.9)***	60.4 (55.5 – 65.4)
Drug and Pharmacy						
1 mile buffer	204 (28.9)	98 (13.9)	82.7 (75.2 – 90.2)	79.7 (76.5 – 82.9)	39.7 (32.9 – 46.6)	80.1 (74.6 – 85.7)
2 mile buffer	204 (28.9)	157 (22.3)	76.4 (69.8 – 83.1)	84.7 (81.7 – 87.7)	**58.8 (51.9 – 65.7)***	82.8 (77.6 – 88.1)
3 mile buffer	204 (28.9)	204 (28.9)	**68.1 (61.7 – 74.5)***	**87.0 (84.1 – 90.0)***	**68.1 (61.6 – 74.7)***	81.6 (76.1 – 87.0)
5 mile buffer	204 (28.9)	285 (40.4)	**54.7 (49.0 – 60.5)***	**88.6 (85.5 – 91.6)***	**76.5 (70.5 – 82.4)***	74.9 (68.8 – 81.0)
Dollar and Variety						
1 mile buffer	278 (39.4)	104 (14.8)	88.5 (82.3 – 94.6)	69.1 (65.4 – 72.7)	33.1 (27.4 – 38.7)	71.9 (66.5 – 77.3)
2 mile buffer	278 (39.4)	196 (27.8)	83.2 (77.9 – 88.4)	**77.4 (73.8 – 81.0)***	**58.6 (52.7 – 64.5)***	79.0 (74.1 – 83.9)
3 mile buffer	278 (39.4)	278 (39.4)	**75.5 (70.5 – 80.6)***	**84.1 (80.6 – 87.5)***	**75.5 (70.4 – 80.7)***	80.7 (76.0 – 85.4)
5 mile buffer	278 (39.4)	391 (55.5)	**59.8 (55.0 – 64.7)***	**86.0 (82.1 – 89.8)***	**84.2 (79.8 – 88.6)***	71.5 (66.1 – 76.9)
Franchised Fast Food						
1 mile buffer	189 (26.8)	113 (16.0)	82.3 (75.3 – 89.3)	83.8 (80.8 – 86.8)	49.2 (41.9 – 56.5)	83.5 (78.2 – 88.9)
2 mile buffer	189 (26.8)	192 (27.2)	71.4 (65.0 – 77.7)	**89.9 (87.3 – 92.5)***	**72.5 (66.0 – 79.0)***	84.8 (79.6 – 90.0)
3 mile buffer	189 (26.8)	247 (35.0)	**62.8 (56.7 – 68.8)***	**92.6 (90.2 – 95.0)***	**82.0 (76.4 – 87.6)***	82.1 (76.6 – 87.7)
5 mile buffer	189 (26.8)	342 (48.5)	**48.5 (43.2 – 53.8)***	**93.7 (91.2 – 96.2)***	**87.8 (83.1 – 92.6)***	71.8 (65.2 – 78.3)

*Non-overlapping confidence intervals are an indication that the statistics were significantly different vs. 1 mile buffer (reference group)

References

1. Caspi CE, Sorensen G, Subramanian SV, Kawachi I: The local food environment and diet: a systematic review. *Health Place* 18:1172-1187, 2012

2. McKinnon RA, Reedy J, Morrissette MA, Lytle LA, Yaroch AL: Measures of the food environment: a compilation of the literature, 1990-2007. *Am J Prev Med* 36:S124-S133, 2009

3. Charreire H, Casey R, Salze P, Simon C, Chaix B, Banos A, Badariotti D, Weber C, Oppert JM: Measuring the food environment using geographical information systems: a methodological review. *Public Health Nutr* 13:1773-1785, 2010

4. Van ME, Lawson AB, Colabianchi N, Nichols M, Hibbert J, Porter D, Liese AD: Spatial Accessibility and Availability Measures and Statistical Properties in the Food Environment. *Spat Spatiotemporal Epidemiol* 2:35-47, 2011

5. Thornton LE, Pearce JR, Kavanagh AM: Using Geographic Information Systems (GIS) to assess the role of the built environment in influencing obesity: a glossary. *Int J Behav Nutr Phys Act* 8:71, 2011

6. Mujahid MS, ez Roux AV, Morenoff JD, Raghunathan T: Assessing the measurement properties of neighborhood scales: from psychometrics to ecometrics. *Am J Epidemiol* 165:858-867, 2007

7. Caspi CE, Kawachi I, Subramanian SV, Adamkiewicz G, Sorensen G: The relationship between diet and perceived and objective access to supermarkets among low-income housing residents. *Soc Sci Med* 75:1254-1262, 2012

8. Moore LV, ez Roux AV, Nettleton JA, Jacobs DR, Jr.: Associations of the local food environment with diet quality--a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. *Am J Epidemiol* 167:917-924, 2008

9. Moore LV, ez Roux AV, Brines S: Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment. *J Urban Health* 85:206-216, 2008

10. Lytle LA, Murray DM, Perry CL, Story M, Birnbaum AS, Kubik MY, Varnell S: School-based approaches to affect adolescents' diets: results from the TEENS study. *Health Educ Behav* 31:270-287, 2004

11. Sharkey JR: Measuring potential access to food stores and food-service places in rural areas in the U.S. *Am J Prev Med* 36:S151-S155, 2009

12. Raudenbush SW, Sampson RJ: Ecometrics: toward a science of assessing ecological settings, with application to the systematic social observation of neighborhoods. *Sociol Method* 29:1-41, 1999

13. Freedman DA, Bell BA: Access to healthful foods among an urban food insecure population: perceptions versus reality. *J Urban Health* 86:825-838, 2009

14. Gustafson AA, Sharkey J, Samuel-Hodge CD, Jones-Smith J, Folds MC, Cai J, Ammerman AS: Perceived and objective measures of the food store environment and the association with weight and diet among low-income women in North Carolina. *Public Health Nutr*1-7, 2011

15. Zenk SN, Schulz AJ, Lachance LL, Mentz G, Kannan S, Ridella W, Galea S: Multilevel correlates of satisfaction with neighborhood availability of fresh fruits and vegetables. *Ann Behav Med* 38:48-59, 2009

16. Williams LK, Thornton L, Ball K, Crawford D: Is the objective food environment associated with perceptions of the food environment? *Public Health Nutr*1-8, 2011

17. Moore LV, ez Roux AV, Franco M: Measuring Availability of Healthy Foods: Agreement Between Directly Measured and Self-reported Data. *Am J Epidemiol* 2012

18. Zenk SN, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML: Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit. *Am J Public Health* 95:660-667, 2005

19. Hearst MO, Pasch KE, Laska MN: Urban v. suburban perceptions of the neighbourhood food environment as correlates of adolescent food purchasing. *Public Health Nutr* 15:299-306, 2012

20. Keita AD, Casazza K, Thomas O, Fernandez JR: Neighborhood perceptions affect dietary behaviors and diet quality. *J Nutr Educ Behav* 43:244-250, 2011

21. Sharkey JR, Horel S, Dean WR: Neighborhood deprivation, vehicle ownership, and potential spatial access to a variety of fruits and vegetables in a large rural area in Texas. *Int J Health Geogr* 9:26, 2010

22. Liese AD, Colabianchi N, Lamichhane AP, Barnes TL, Hibbert JD, Porter DE, Nichols MD, Lawson AB: Validation of 3 food outlet databases: completeness and geospatial accuracy in rural and urban food environments. *Am J Epidemiol* 172:1324-1333, 2010

23. Liese AD, Barnes TL, Lamichhane AP, Hibbert JD, Colabianchi N, and Lawson AB. Characterizing the Food Retail Environment: Impact of Count, Type and Geospatial Error in Two Secondary Data Sources. Journal of Nutrition Education and Behavior . 2013.

24. Powell LM, Han E, Zenk SN, Khan T, Quinn CM, Gibbs KP, Pugach O, Barker DC, Resnick EA, Myllyluoma J, Chaloupka FJ: Field validation of secondary commercial data sources on the retail food outlet environment in the U.S. *Health Place* 17:1122-1131, 2011

25. Larson NI, Story MT, Nelson MC: Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med* 36:74-81, 2009

26. Bodor JN, Rose D, Farley TA, Swalm C, Scott SK: Neighbourhood fruit and vegetable availability and consumption: the role of small food stores in an urban environment. *Public Health Nutr* 11:413-420, 2008

27. Jeffery RW, Baxter J, McGuire M, Linde J: Are fast food restaurants an environmental risk factor for obesity? *Int J Behav Nutr Phys Act* 3:2, 2006

28. Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ: Proximity of supermarkets is positively associated with diet quality index for pregnancy. *Prev Med* 39:869-875, 2004

29. Wang MC, Kim S, Gonzalez AA, MacLeod KE, Winkleby MA: Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. *J Epidemiol Community Health* 61:491-498, 2007

30. Jago R, Baranowski T, Baranowski JC, Cullen KW, Thompson D: Distance to food stores & adolescent male fruit and vegetable consumption: mediation effects. *Int J Behav Nutr Phys Act* 4:35, 2007

31. Coulton CJ, Korbin J, Chan T, Su M: Mapping residents' perceptions of neighborhood boundaries: a methodological note. *Am J Community Psychol* 29:371-383, 2001

32. Coulton CJ, Jennings MZ, Chan T: How Big is My Neighborhood? Individual and Contextual Effects on Perceptions of Neighborhood Scale. *Am J Community Psychol* 2012

33. Guest AM, Lee BA: How urbanites define their neighborhoods. *Population and Environment* 7:32-56, 1984

34. Lee BA, Campbell KE, Miller O: Racial differences in urban neighboring. *Sociological Forum* 6:525-550, 1991

35. Appleyard D: Styles and methods of structuring a city. *Environment and Behavior* 2:100-116, 1970

36. Goodchild B: Class differences in environmental perception. *Urban Studies* 11:157-169, 1974

37. Haney W, Knowles E: Perception of neighborhoods by city and suburban residents. *Human Ecology* 6:210-214, 1978

38. Ma X, Barnes TL, Freedman DA, Bell BA, Colabianchi N, and Liese AD. Test-retest reliability of a questionnaire measuring perceptions of neighborhood food environment. Health & Place . 2013.

39. Liese AD, Bell BA, Barnes TL, Colabianchi N, Hibbert JD, Blake CE, and Freedman DA. Environmental influences on fruit and vegetable intake: Results from a path analytic model. American Journal of Preventive Medicine . 2013.

40. American Association for Public Opinion Research (AAPOR). Standard Definitions, Final Dispositions of Case Codes and Outcome Rates for Surveys. American Association for Public Opinion Research . 2011.

41. Hu SS, Balluz L, Battaglia MP, Frankel MR: Improving public health surveillance using a dual-frame survey of landline and cell phone numbers. *Am J Epidemiol* 173:703-711, 2011

42. Franco M, ez Roux AV, Glass TA, Caballero B, Brancati FL: Neighborhood characteristics and availability of healthy foods in Baltimore. *Am J Prev Med* 35:561-567, 2008

43. Block D, Kouba J: A comparison of the availability and affordability of a market basket in two communities in the Chicago area. *Public Health Nutr* 9:837-845, 2006

44. Centers for Disease Control and Prevention (CDC): State Indicator Report on Fruits and Vegetables. [article online], 2009. Accessed 28 April 2011

45. Centers for Disease Control and Prevention (CDC): Behavioral Risk Factor Surveillance System Survey Data. [article online], 2011.

46. Washington State Department of Health: Guidelines for Using Rural-Urban Classification Systems for Public Health Assessment. [article online], 2009. Accessed 23 December 2009

47. Paquet C, Daniel M, Kestens Y, Leger K, Gauvin L: Field validation of listings of food stores and commercial physical activity establishments from secondary data. *Int J Behav Nutr Phys Act* 5:58, 2008

48. Janse AJ, Gemke RJ, Uiterwaal CS, van dT, I, Kimpen JL, Sinnema G: Quality of life: patients and doctors don't always agree: a meta-analysis. *J Clin Epidemiol* 57:653-661, 2004

49. Forsyth A, Lytle L, Riper DV: Finding food: Issues and challenges in using Geographic Information Systems to measure food access. *J Transp Land Use* 3:43-65, 2010

CHAPTER 5

MANUSCRIPT 2

Title: Examining the Relationship between GIS-based Measures of Food Outlets and Perceived Availability of Healthy Foods

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Key words: GIS, Food Environment, Food Outlets, Healthy Foods, Perceptions

Abstract

Geographic information systems (GIS) have been the most utilized tool to characterize the food environment; however, self-report perception measures have increased in frequency. Telephone survey data from 705 residents in an eight-county region of South Carolina were used to examine the relationship between GIS-based measures of food outlets and resident's perceived availability of healthy foods. Whereas the number of food outlets in a neighborhood may not be a significant predictor of perceived availability of healthy foods, the distance to the nearest food outlet may be, depending on whether a resident lives in an urban or non-urban neighborhood.

Introduction

Studies linking diet to supermarket availability and proximity began to appear over ten years ago in an effort to address environmental influences on individual behaviors and obesity (1) (2) (3) (4) (5) (6) (7) (8). Since then non-traditional retail food outlets such as convenience stores and franchised fast food restaurants have also been studied (5) (4). Characterizations of retail food outlet availability have been a predominant method to describe an individual's food environment, typically characterized by geographic information systems (GIS) (9) (10) (5). Two dimensions of GIS-based measures include *availability* defined as the presence or number of food retail outlets in a given geographical area (9) (10) and *accessibility* defined as the ease of access to available food outlets, taking into consideration factors such as travel distance, time, and financial resources (9). Distance to the nearest food retailer has been most commonly used (11) (10).

Recently the use of perception measures based on individuals' self-report has gained in popularity to describe the food environment. Similar to the GIS-based measures of an individual's food environment, perception measures have also focused on perceived availability and accessibility of specific food items and retail food stores (12). However, GIS-based measures which are typically limited to the location and type of outlet and are based on secondary data sources that may contain many inaccuracies (13). Further, validation of GIS-based measures is often not feasible due to resources and the expense of research staff to travel into the field (14). It has been suggested that it may be cheaper and more accurate if perceptions measures are utilized, either alone or in tandem with GIS-based measurements (12). In addition, individuals' perceptions may become an

important method to explore residents' shopping behaviors such as distances traveled to a food outlet and store utilization (12) (15)

To date, a number of studies have examined relationships between GIS-based measures and perceptions of the food environment (16,17) (18) (19) (20) (21) (22) (23) (24). Many of these studies have focused on the perceived availability of healthy foods, i.e. fresh fruits and vegetables and low fat foods, compared to either direct, objective measures of these food items (16) (17) (18) (19) (20) (21) (22) or the perceived presence of food stores compared to GIS-based presence (19) (20) (21) (12).

Specifically, a study by Moore et al. (2008), reported that residents living in areas with lower densities of supermarkets rated the selection and availability of fruits and vegetables and low fat foods 17% lower than those living in areas with the highest densities of supermarkets (17). Another study by Gustafson et al. (2011) have reported less conclusive findings (19). However, these studies have limitations. In both Moore et al. and Gustafson et al., the GIS-based measures of food stores were characterized by secondary data sources and not validated by field work. In addition, each study only captured supermarkets or a combination of food outlets (i.e. supermarkets and convenience stores) and did not address non-traditional food outlets specifically, e.g. dollar and variety stores, convenience stores, or drug and pharmacy stores. The studies also did not consider multiple outlet types in the analyses when examining the association between perceived availability of healthy foods and the GIS-based measures. Lastly, the neighborhood context in which study participants lived i.e. urban or rural was not taken into consideration. The published literature on the food environment has predominately

focused on urban communities with high population densities (12) (25). Few studies have incorporated or focused on rural or non-urban communities (25).

The objective of this study was to examine the relationship between the GIS-based measures of the food environment and perception-based measures. Specifically, we examine the relationship between the availability and accessibility measures of various food outlet types using GIS methods compared against residents' perceptions of healthy food availability within their neighborhood. We hypothesize that GIS-based measures of supermarkets will have a positive association with perceived availability of healthy foods while GIS-based measures of non-traditional and fast food outlets will have a negative association with perceived availability of healthy foods. Secondarily, we examined these relationships by stratifying residence into urban or non-urban neighborhoods. Its hypothesized that residents living in non-urban neighborhoods will have a stronger association between GIS-based and the perceived availability of healthy foods.

Methods

Study Region

The study area consisted of a contiguous geographical area encompassing a total of eight counties (seven rural and one urban) in the Midlands region of the state of South Carolina (SC). The urban county, Richland, contains the state capital, Columbia, which is in the middle of the state. The seven non-urban counties (Calhoun, Chester, Clarendon, Fairfield, Kershaw, Lancaster, and Orangeburg) comprise the remaining study area. The study has been previously described (26) (13).

Recruitment

This study was approved by the University of South Carolina Institutional Review Board.

For this cross-sectional study, a geographically-based sample of 968 adults serving as the primary food shoppers of their household was recruited in the eight-county study region between April and June of 2010. The sample of households was generated from a random selection of landline telephone numbers with listed addresses restricted to within 64 eligible ZIP codes. To achieve a good spatial coverage of the entire study area, research staff aimed to interview approximately 15 respondents per ZIP code. Recruitment calls were made by the interviewing staff of the University of South Carolina (USC) Survey Research Laboratory (SRL). During the telephone calls, respondents were screened with respect to meeting the eligibility criteria including being a) at least 18 years old, b) the primary food shopper, c) capable of speaking English, and d) living in the eight county study area. Of the 2,477 household telephone numbers screened, a total of 968 were eligible and completed the interview. There were 553 refusals, 377 ineligibles, and 579 of non-contact, unknown, or other status. Applying the American Association for Public Opinion Research Response Rate Formula 4 (27), we estimated a response rate of 47%, which is very comparable to the 49% among landline households achieved in a recent evaluation of the Behavioral Risk Factor Surveillance System landline response rates conducted in 18 US states (28).

For analyses, participants were removed from the larger sample if missing any data on individual characteristics (age, 71; race/ethnicity,73; education, 69; employment status, 68; household income, 215; SNAP status, 69; spouse or partner, 64; number of

household members, 74), GIS-based availability and accessibility measures (19), perceived availability of healthy foods (5), and urbanicity (18). This resulted in a final sample of 705 residents for analyses.

Perceived Availability of Healthy Foods

Perceptions of the food environment were ascertained with a previously validated instrument (29) which assessed the availability of healthy food options within a resident's neighborhood defined as 1 mile buffer or 20 minute walk. Survey participants indicated their agreement on a 5-point Likert scale with the following statements: (1) A large selection of fruits and vegetables is available in my neighborhood, (2) the fresh fruits and vegetables in my neighborhood are of high quality, and (3) a large selection of low-fat products is available in my neighborhood. For analysis, each question was reverse coded, and aggregated into a summary score with 0 indicating worst availability of healthy foods and 12 indicating best availability. The properties of the score have been validated in our study sample, resulting in a test-retest reliability measure of 0.71 (95% CI: 0.60, 0.80) (30).

GIS-based Availability and Accessibility Measures of the Food Environment

All geo-spatial analyses were conducted using ArcGIS 10.0 (ESRI Redlands, CA 2010). GIS-based measures were calculated using the geocoded residents' home address as the point of reference with a one-mile street and road network buffer representing their neighborhood boundary. The addresses were then linked with an existing, validated geospatial database on the food retail outlets (26) (13) and the number of food outlets

within the buffer (i.e. availability) and the distance to the nearest food outlet (i.e. accessibility) of each type were calculated using the shortest street distance based on the TIGER 2008 road network (U.S. Census TIGER/Line, 2008) (31). The food outlet types included supermarkets, supercenters, warehouse clubs, convenience stores, drug and pharmacy stores, dollar and variety stores, and franchised fast food restaurants. Supermarkets, supercenters, and warehouse clubs were all aggregated and considered as "supermarkets".

Resident Characteristics

The telephone survey also included questions on demographic and socio-economic characteristics. These questions were largely based on the Behavioral Risk Factor Surveillance Survey (BRFSS) (32). Age (in years) and the number of individuals living in a participant's household were both continuous variables. Race/ethnicity was categorized as Non-Hispanic White and Minority (Non-Hispanic Black or African American, Hispanic, and/or other). Annual household income was categorized as less than $20,000 or $20,000 or more. Education consisted of 3 groups: (1) not a high school graduate, (2) high school graduate or GED only, and (3) some college or higher. Partner and SNAP status were both dichotomous, coded as "yes" or "no". Employment status was a categorical variable grouped as employed, not employed, or retired. Each resident was classified individually with respect to level of urbanicity using the a 2010 U.S. Census defined urban classification (33) via a point-in-polygon operation within ArcGIS.

Statistical Analyses

Ordinary Least Square (OLS) regression models were used to assess the relationship between the GIS-based availability and accessibility of food retail outlets and the perceived availability of healthy foods in residents' neighborhoods. Covariates included age, gender, race/ethnicity, education, employment, household income, SNAP utilization, partner status, household size, and urbanicity. Assumptions for OLS regression included independent observations and linearity, homoscedasticity, and normality of the residuals. No violations were noted and multicolinearity was tested using variance inflation factors (VIF) and tolerance. To examine the independent influence of each GIS-based food outlet measure, without controlling for the other food outlet types, we examined separate models in which availability and accessibility for only one GIS-based food outlet type was included in addition to covariates. Next, we examined models in which all GIS-based measures for each food outlet types were included. The R^2 of each model was examined to determine how much each model explained the variance in the outcome, perceived availability of healthy foods. The Unique R^2 was used to examine the unique contributions of each GIS-based food outlet measure made in explaining the variation in the perceived availability of healthy foods. Final models were also stratified by urbanicity to examine relationships between GIS-based measures of the food environment and perceived availability of healthy foods in urban and non-urban residents separately.

Results

Participants in this study were majority female (77.7%), Non-Hispanic White (65.5%), and lived in non-urban neighborhoods (77.5%;Table 1). On average, they were

57 years old with more than half of the participants having some college education or higher (53.1%). Only, 11% of participants did not have a high school diploma or GED. Nearly 32% of participants were unemployed and 29% had a household income less than $20,000 per year. Sixty-four percent had a spouse or partner in the household. Characteristics did not differ by urbanicity when considering age, gender, race, spouse/partner, or SNAP utilization; however, there were significant differences between urban and non-urban residents when considering education, employment status, and household income. Specifically, a higher percentage of urban residents had some college education or higher, were employed, and had an income of at least $20,000 per year or higher compared to non-urban residents.

The mean number of food outlets in the neighborhoods of the study sample was quite low, ranging from 0.1 for supermarkets to 0.9 for convenience stores (Table 2), which is understandable given the distribution of outlets because many participants did not have any of the food outlet types near their home. For example, 88.7% of residents did not have a supermarket in their neighborhood and 71.5% of residents did not have a convenience store (distributions not shown). The mean distance to the nearest supermarket from a resident's home was 5.9 miles while the distances for non-traditional food outlets ranged from 2.9 miles for convenience stores to 7.8 miles for a drug and pharmacy stores. Finally, the mean perceived availability of healthy foods score was 6.2 on a scale of 12 for the entire study sample

Table 3 displays the results for separate OLS models examining the relationship between the number and distance to nearest measures for each food outlet type and the perceived availability of healthy foods. Overall, results from the models show that an

increase in the number of food outlet type was significantly associated with an increase in perceived availability of healthy foods. Moreover, each food outlet type alone was found to be significantly associated with an increase in perceived availability of healthy foods. The number of supermarkets had the strongest association (β =1.27) followed by drug and pharmacy stores (β =0.93). When examining distance to the nearest food outlet, each measure was also significantly associated with perceived availability of healthy foods. Specifically, the GIS-based accessibility for each food outlet type was inversely related to perceived availability of healthy foods. Thus, as the distance to the nearest food outlet increased, the perceived availability of healthy foods decreased.

The final OLS models accounting for GIS-based measures for all food outlet types are displayed in Table 4. When accounting for all food outlet types, there were no significant associations between the number of food outlets – of any type - and perceived availability of healthy foods in the total sample of residents. However in non-urban residents, there was a significant positive association between count of convenience stores and perceived availability of healthy foods (β=0.45). Moreover, convenience stores accounted for a 1% of the variation in the model.

Overall, distance to the nearest supermarket had a significant inverse relationship with perceived availability of healthy foods when accounting for distance to all other food outlets. The relationship was strongest for urban residents (β=-1.73) explaining 9% of the variation in those residents. Additionally, as the distance to the nearest dollar and variety store increased, the perceived availability of healthy foods decreased. This relationship was not observed in urban residents alone, but was observed in non-urban residents. Lastly, the distance to the nearest franchised fast food restaurant was also

significantly positively associated with perceived availability of healthy food. Thus, as distance to the nearest fast food outlet increased, the perceived availability of healthy foods also increased. However, like dollar and variety stores, this seemed to be an effect reserved to non-urban residents.

Discussion

Our study found that the availability of food outlets within a one mile network buffer of residence - including supermarkets - was not a significant predictor of perceived availability of healthy foods. However, distance to the nearest food outlets, specifically supermarkets, dollar and variety, and fast food restaurants, were all significantly associated with perceived availability. These findings differ from previous studies that have suggested a significant positive association between supermarket availability, either by presence or number of stores, with perceived availability of healthy foods (17) (19). In a study by Moore et al. (2008), residents living in areas with lower densities of supermarkets reported a lower selection and availability of healthy foods compared to areas with high densities of supermarkets (17). However, this study did not adjust for other food outlet types in their analyses. In another study, Gustafson et al. (2011) found that individuals with a convenience store and a supercenter present had higher odds of perceiving their neighborhood high in healthy food availability (19). However in the same study, Gustafson et al. did not find a significant association when considering supermarkets, supercenters, and convenience stores separately (19).

Differences between our study and previous research may lie in the use of various food outlet types including supermarkets and non-traditional food outlets. Moreover,

both Moore et al. and Gustafson et al. evaluated the relationship between the GIS-based measure of a food outlet and perceived availability of healthy foods using each outlet type separately in models compared to the inclusion of all outlet types. Participants in our study also lived in different neighborhood settings compared to previous studies. Specifically, our study examined residents in both urban and non-urban settings defined by a 1 mile street buffer around their home address. Gustafson et al's study encompassed six counties with both metro and non-metro settings, but neighborhood boundaries were defined by the Census tract which may vary considerably in size and the perceived availability of healthy foods were defined as the area approximately 5 miles around their home address. Both measurement parameters differed greatly compared to our study.

The study by Moore et al. included residents living in North Carolina, Maryland, and New York with areas differing in population density and urbanicity(17). Given these differences, Moore and et al. found evidence of regional variation in the relationship between store densities and perceived availability of healthy foods. For example, supermarket density was found to be most strongly associated with perceived availability of healthy foods in North Carolina compared to the higher populated areas of Maryland and New York (17). In our study we found when stratifying by urbanicity that the relationship between the availability (number of stores) for any food outlet type was not significantly associated with perceived availability of healthy foods in urban residents in the final model. In contrast, the perceived availability of healthy foods increased significantly as the number of convenience stores increased in non-urban residents.

In addition to the analyses focusing on availability, our study also included analyses examining measures of accessibility i.e. distance to the nearest food outlet. We found that as the distance to the nearest supermarket or dollar and variety store increased, the perceived availability score decreased significantly. Contrarily, perceived availability of healthy foods increased as the distance to the nearest franchised fast food increased. However, these effects seemed to be driven by non-urban residential status compared to those individual living in urban neighborhoods for all associations except for supermarkets. To our knowledge, no studies have examined the GIS-based accessibility measure, distance to nearest, and the summed perceived availability of healthy foods score.

Our study aimed to examine the relationship between two types of food environment measures i.e. GIS-based and perceived measures. Specifically, understanding the relationship between different measures of the food environment could improve the interpretations of food environment studies and the development of better measurement instruments in the future (17). In a recent review of the local food environment and diet, perceived measures of availability were consistently related to healthy dietary outcomes, however, GIS-based availability measures were less conclusive (12). As for accessibility, both GIS-based and perceived measures have demonstrated weak and inconsistent findings as it relates to dietary intake (12). Measurement error due to unidentified food outlets, poor type classification, and spatial assignment may contribute to these weak associations with GIS-based measures based on secondary data sources (17) (13). Alternatively, influences such as residents' personal experiences, preferences, and behaviors may influence their awareness of food shopping opportunities

in their neighborhood environment (17) as well as how they define the concept of "neighborhood" (34) (35).

Our study has several limitations. First, we selected the household food shopper as the respondent, which resulted in a predominately female sample. Second, our landline-based telephone sample yielded an age distribution with an average age in the middle-to-older age category. We only had a survey response rate of 47%, however, this comparable to the 49% among landline households achieved in a recent evaluation of the Behavioral Risk Factor Surveillance System landline response rates (28) and to the response rate reported by Moore et al. in 2008 (17). A final limitation is that there was about a one year interval in the timing between the completion of the food environment validation study and the perceptions survey, however this is a similar or shorter time gap than other studies (17) (19). The study by Gustafson et al. had a gap between 1-3 years and Moore et al. had a difference of a little less than one year for collecting perceived and GIS-based measures.

Strengths of our study include the use of GIS-based measures established by validated field work (26) (13). Moreover, previous researchers such as Moore et al. and Gustafson et al., have used GIS-based measures using secondary data sources and not validated in by field census. In addition, our study area contained both urban and non-urban communities and may be beneficial and comparable to any new studies examining populations in the Southeastern United States. Third, our study included both GIS-based availability and accessibility measures of food outlets and included not only supermarkets, but many non-traditional food outlets. Previous studies have limited

analyses to only a few food outlet types and availability measures such as presence or count of stores.

The results from this study suggest that the accessibility, not the availability, of food outlets is a significant predictor of perceived healthy food options in a person's neighborhood food environment. This study contributes to the literature as it relates to understanding and developing better techniques to characterize individuals' food choices in their environment. However, additional research will be needed to determine whether GIS-based, perceptions, or both are the best approach to examine how the food environment influences individuals' shopping and eating behaviors.

Table 5.1. Descriptive Statistics of Residents' Characteristics, N=705

		n (%) or **Mean (SD)**
Age (years)		**56.5 (14.7)**
Gender	Male	157 (22.3)
	Female	548 (77.7)
Race/Ethnicity	Minority (NHB, Hispanic, or Other)	243 (34.5)
	NHW	462 (65.5)
Education	< HS diploma or GED	80 (11.4)
	HS diploma or GED	251 (35.6)
	Some College or Higher	374 (53.1)
Employment Status	Not Employed	159 (22.6)
	Retired	222 (31.5)
	Employed	324 (46.0)
Household Income	< $20,000 per year	204 (28.9)
	≥ $20,000 per year	501 (71.1)
SNAP Status	No	635 (90.1)
	Yes	70 (9.9)
Spouse or Partner	No	253 (35.9)
	Yes	452 (64.1)
# of Household Members		**2.5 (1.4)**
Urbanicity	Non-Urban	558 (79.1)
	Urban	147 (20.9)

Table 5.2. Descriptive Statistics of Perceived and GIS-based Food Environment Measures, N=705

	Mean (SD)
Perceived Availability of Healthy Foods	
Availability of Healthy Foods (Scoring Range: 0-12)	6.2 (3.6)
GIS-based Food Outlet Measures	
Availability of Retail Food Outlets (Number *within 1 mile buffer*)	
Supermarkets	0.1 (0.5)
Convenience	0.9 (1.9)
Drug and Pharmacy	0.2 (0.6)
Dollar and Variety	0.2 (0.7)
Franchised Fast Food	0.6 (1.8)
Accessibility of Retail Food Outlets (Distance to nearest *in miles*)	
Supermarkets	5.9 (4.5)
Convenience	2.9 (2.6)
Drug and Pharmacy	7.8 (5.9)
Dollar and Variety	5.1 (4.1)
Franchised Fast Food	6.1 (5.1)

Table 5.3. Relationship Between GIS-based Food Outlet Measures and Perceived Availability of Healthy Foods, Models For Each Food Outlet Type Separately, N=705

	Unique R^2	β	SE	P-value	Model R2
Availability of Retail Food Outlets (Number *within 1 mile buffer*)					
Supermarkets	*0.02*	**1.27**	**0.29**	**<0.0001**	*0.14*
Convenience	*0.03*	**0.33**	**0.07**	**<0.0001**	*0.14*
Drug and Pharmacy	*0.02*	**0.93**	**0.24**	**0.0002**	*0.13*
Dollar and Variety	*0.02*	**0.72**	**0.19**	**0.0002**	*0.13*
Franchised Fast Food	*0.01*	**0.21**	**0.08**	**0.0067**	*0.12*
Accessibility of Retail Food Outlets (Distance to nearest *in miles*)					
Supermarkets	*0.04*	**-0.18**	**0.03**	**<0.0001**	*0.15*
Convenience	*0.02*	**-0.20**	**0.05**	**0.0001**	*0.13*
Drug and Pharmacy	*0.01*	**-0.07**	**0.03**	**0.0090**	*0.12*
Dollar and Variety	*0.04*	**-0.20**	**0.03**	**<0.0001**	*0.16*
Franchised Fast Food	*0.01*	**-0.07**	**0.03**	**0.0178**	*0.12*

Note: All models adjusted for age, gender, race/ethnicity, education, employment status, household income, SNAP status, spouse or partner, # of household members, and urbanicity

Table 5.4. Relationship Between GIS-based Food Outlet Measures and Perceived Availability of Healthy Foods, Final Model With All Food Outlet Types, N=705

	All*				**Urban** N=147				**Non-Urban** N=558			
	Unique R^2	β	SE	P-value	Unique R^2	β	SE	P-value	Unique R^2	β	SE	P-value
Availability of Retail Food Outlets (Number *within 1 mile buffer*)												
Supermarkets	0.005	0.76	0.39	0.0515	0.02	0.65	0.42	0.1262	0.004	1.11	0.76	0.1442
Convenience	0.005	0.22	0.12	0.0552	0.00005	0.01	0.15	0.9329	**0.01**	**0.45**	**0.18**	**0.0128**
Drug and Pharmacy	0.0002	0.14	0.35	0.6810	0.005	0.36	0.41	0.3875	0.0002	0.18	0.56	0.7436
Dollar and Variety	0.0005	0.16	0.25	0.5152	0.0008	0.15	0.44	0.7206	0.0008	-0.26	0.39	0.5080
Franchised Fast Food	0.0009	-0.09	0.11	0.3852	0.0009	-0.04	0.11	0.7188	0.0001	0.05	0.23	0.8386
Model R^2	*0.13*				*0.14*				*0.07*			
Accessibility of Retail Food Outlets (Distance to nearest *in miles*)												
Supermarkets	**0.01**	**-0.16**	**0.05**	**0.0022**	**0.09**	**-1.73**	**0.44**	**0.0001**	**0.01**	**-0.15**	**0.06**	**0.0082**
Convenience	0.0001	-0.02	0.07	0.7927	0.002	0.24	0.39	0.5312	0.0001	-0.01	0.07	0.8526
Drug and Pharmacy	0.00001	0.002	0.04	0.9465	0.002	-0.25	0.40	0.5293	0.00004	0.006	0.04	0.8808
Dollar and Variety	**0.01**	**-0.15**	**0.05**	**0.0044**	0.01	0.49	0.38	0.1954	**0.01**	**-0.16**	**0.06**	**0.0047**
Franchised Fast Food	**0.01**	**0.11**	**0.05**	**0.0136**	0.004	0.43	0.50	0.3843	**0.01**	**0.11**	**0.05**	**0.0237**
Model R^2	*0.17*				*0.17*				*0.09*			

Note. All models adjusted age, gender, race/ethnicity, education, employment status, household income, SNAP status, spouse or partner, and # of household members

*Adjusted for urbanicity

References

1. Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ: Proximity of supermarkets is positively associated with diet quality index for pregnancy. *Prev Med* 39:869-875, 2004

2. Morland K, Wing S, Diez RA, Poole C: Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med* 22:23-29, 2002

3. Rose D, Richards R: Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. *Public Health Nutr* 7:1081-1088, 2004

4. Cummins S, Macintyre S: Food environments and obesity--neighbourhood or nation? *Int J Epidemiol* 35:100-104, 2006

5. Larson NI, Story MT, Nelson MC: Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med* 36:74-81, 2009

6. Morland K, ez Roux AV, Wing S: Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. *Am J Prev Med* 30:333-339, 2006

7. Morland KB, Evenson KR: Obesity prevalence and the local food environment. *Health Place* 15:491-495, 2009

8. Inagami S, Cohen DA, Finch BK, Asch SM: You are where you shop: grocery store locations, weight, and neighborhoods. *Am J Prev Med* 31:10-17, 2006

9. Thornton LE, Pearce JR, Kavanagh AM: Using Geographic Information Systems (GIS) to assess the role of the built environment in influencing obesity: a glossary. *Int J Behav Nutr Phys Act* 8:71, 2011

10. Charreire H, Casey R, Salze P, Simon C, Chaix B, Banos A, Badariotti D, Weber C, Oppert JM: Measuring the food environment using geographical information systems: a methodological review. *Public Health Nutr* 13:1773-1785, 2010

11. Van Meter EM, Lawson AB, Colabianchi N, Nichols M, Hibbert J, Porter DE, Liese AD: An evaluation of edge effects in nutritional accessibility and availability measures: a simulation study. *Int J Health Geogr* 9:40, 2010

12. Caspi CE, Kawachi I, Subramanian SV, Adamkiewicz G, Sorensen G: The relationship between diet and perceived and objective access to supermarkets among low-income housing residents. *Soc Sci Med* 75:1254-1262, 2012

13. Liese AD, Barnes TL, Lamichhane AP, Hibbert JD, Colabianchi N, and Lawson AB. Characterizing the Food Retail Environment: Impact of Count, Type and Geospatial Error in Two Secondary Data Sources. Journal of Nutrition Education and Behavior . 2013.

14. Forsyth A, Lytle L, Riper DV: Finding food: Issues and challenges in using Geographic Information Systems to measure food access. *J Transp Land Use* 3:43-65, 2010

15. Caspi CE, Sorensen G, Subramanian SV, Kawachi I: The local food environment and diet: a systematic review. *Health Place* 18:1172-1187, 2012

16. Moore LV, ez Roux AV, Nettleton JA, Jacobs DR, Jr.: Associations of the local food environment with diet quality--a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. *Am J Epidemiol* 167:917-924, 2008

17. Moore LV, ez Roux AV, Brines S: Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment. *J Urban Health* 85:206-216, 2008

18. Freedman DA, Bell BA: Access to healthful foods among an urban food insecure population: perceptions versus reality. *J Urban Health* 86:825-838, 2009

19. Gustafson AA, Sharkey J, Samuel-Hodge CD, Jones-Smith J, Folds MC, Cai J, Ammerman AS: Perceived and objective measures of the food store environment and the association with weight and diet among low-income women in North Carolina. *Public Health Nutr*1-7, 2011

20. Zenk SN, Schulz AJ, Lachance LL, Mentz G, Kannan S, Ridella W, Galea S: Multilevel correlates of satisfaction with neighborhood availability of fresh fruits and vegetables. *Ann Behav Med* 38:48-59, 2009

21. Williams LK, Thornton L, Ball K, Crawford D: Is the objective food environment associated with perceptions of the food environment? *Public Health Nutr*1-8, 2011

22. Moore LV, ez Roux AV, Franco M: Measuring Availability of Healthy Foods: Agreement Between Directly Measured and Self-reported Data. *Am J Epidemiol* 2012

23. Giskes K, Van Lenthe FJ, Brug J, Mackenbach JP, Turrell G: Socioeconomic inequalities in food purchasing: the contribution of respondent-perceived and actual (objectively measured) price and availability of foods. *Prev Med* 45:41-48, 2007

24. kumar S, Quinn S.C., Kriska AM, Thomas SB: "Food is directed to the area":African Americans' perceptions of the neighborhood nutrition environment in Pittsburgh. *Health & Place* 17:370-378, 2011

25. Gustafson A, Hankins S, Jilcott S: Measures of the consumer food store environment: a systematic review of the evidence 2000-2011. *J Community Health* 37:897-911, 2012

26. Liese AD, Colabianchi N, Lamichhane AP, Barnes TL, Hibbert JD, Porter DE, Nichols MD, Lawson AB: Validation of 3 food outlet databases: completeness and geospatial accuracy in rural and urban food environments. *Am J Epidemiol* 172:1324-1333, 2010

27. American Association for Public Opinion Research (AAPOR). Standard Definitions, Final Dispositions of Case Codes and Outcome Rates for Surveys. American Association for Public Opinion Research . 2011.

28. Hu SS, Balluz L, Battaglia MP, Frankel MR: Improving public health surveillance using a dual-frame survey of landline and cell phone numbers. *Am J Epidemiol* 173:703-711, 2011

29. Echeverria SE, ez-Roux AV, Link BG: Reliability of self-reported neighborhood characteristics. *J Urban Health* 81:682-701, 2004

30. Ma X, Barnes TL, Freedman DA, Bell BA, Colabianchi N, and Liese AD. Test-retest reliability of a questionnaire measuring perceptions of neighborhood food environment. Health & Place . 2013.

31. United States Bureau of Census. 2008 TIGER/Line Shapefiles. 12-8-2008.

32. Centers for Disease Control and Prevention (CDC): Behavioral Risk Factor Surveillance System Survey Data. [article online], 2011.

33. Washington State Department of Health: Guidelines for Using Rural-Urban Classification Systems for Public Health Assessment. [article online], 2009. Accessed 23 December 2009

34. Coulton CJ, Korbin J, Chan T, Su M: Mapping residents' perceptions of neighborhood boundaries: a methodological note. *Am J Community Psychol* 29:371-383, 2001

35. Coulton CJ, Jennings MZ, Chan T: How Big is My Neighborhood? Individual and Contextual Effects on Perceptions of Neighborhood Scale. *Am J Community Psychol* 2012

CHAPTER 6

MANUSCRIPT 3

Title: Perceived Fast Food Opportunities and GIS-based Food Outlet Measures

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Abstract

Geographic information systems (GIS) have frequently been used to define fast food availability in food environment research. However, perception measures may be equally important in understanding how individuals view their environment and make food choices. To date, no study has examined the relationship between perceived fast food availability and GIS-based measures of the food environment. Telephone survey data from 705 residents in an eight-county region of South Carolina were used to examine the relationship between GIS-based food outlet measures and resident's perceived fast food availability. Neither the number of fast food outlets in a neighborhood, nor the distances to the nearest fast food outlet were significant predictors of perceived fast food availability when controlling for all other food outlets. However, GIS-based measures of drug and pharmacy stores and distance to the nearest supermarket were significantly associated with perceived fast food availability. When stratified by urbanicity, the number of fast food outlets was significantly associated with perceived availability in non-urban residents. Findings suggest that GIS-based food outlet measures are not appropriate indicators of how individuals perceive fast food availability given the inconsistent nature of the associations.

Introduction

The relationship between fast food opportunities and diet has become an area of interest in food environment research (1). Foods purchased at fast food restaurants account for nearly 15% of children and adults' diets in the United States (2) (3). Additionally, the number of fast food outlets has increased dramatically over the years (4) (5) (6). Researchers have hypothesized that the greater availability of and access to fast food outlets contribute to the obesity epidemic by promoting unhealthy eating behaviors characterized by higher-calorie meals (4). However, studies examining the influence of fast food outlets have found mixed results when relating fast food restaurant availability to diet quality and weight status (4) (7) (5). Moreover, many studies using geographic information systems (GIS) to measure fast food exposure have not found a relationship between GIS-based fast food availability and fast food consumption (8) (9) (10). In contrast studies using perceived measures of fast food availability have reported significant associations (11) (9).

The choice of fast food availability/opportunity measure could be responsible for inconsistencies between studies. To date, most studies have utilized objective measures of fast food exposure via GIS (4) (12) (13) (14). However, relying on secondary data sources, this approach is subject to inaccuracies in the number of food outlets accounted for, the outlet type designation, and outlets' geospatial locations (4) (15) (16). Individuals' perception of fast food availability has emerged as another method to characterize fast food exposure, however, only a few studies have used perceived (i.e. subjective) measures of fast food availability in relation with fast food consumption and diet quality (11) (9) (17). Specifically, Moore et al. (2009) reported that participants who

lived in areas with higher self-reported exposure to fast food had a 27% higher odds of consuming fast food near their home compared to those who lived in areas with lower reported exposure (9). Ho and colleagues (2010) have found perceived availability of fast food to be significantly associated with higher fast food consumption in a sample of adolescents boys (17). However, to the best of our knowledge the relationship between perceived and GIS-based fast food availability has not been examined.

Furthermore, some researchers have pointed out that identifying fast food restaurants as a sole source of fast food underestimates neighborhood exposure to fast food (18). Studies should consider non-traditional sources such as supermarkets and convenience stores as potential fast food and takeaway sources (18) (19). In addition to types of venues, researchers have shown that fast food outlets and supermarkets tend to cluster geographically (20). Thus, it is possible in a food environment to have supermarkets, fast food chains, and convenience stores in close proximity to one another. Moreover, previous studies have not looked at the association between GIS-based measures of non-traditional fast food outlets and the perception of fast food availability.

In this study, we sought to examine the relationship between individuals' perceived availability of fast food restaurants in their neighborhood and the GIS-based measures of fast food restaurant availability. Additionally, we evaluated the relationship between the perceived availability of fast food restaurants and GIS-based measures of other possible food outlet types such as supermarkets, convenience stores, dollar and variety stores, and drug and pharmacy venues and their impact on the association between the perceived and GIS-based fast food availability.

Methods

This is a cross-sectional study utilizing responses from a telephone survey consisting of 968 primary household food shoppers including GIS-based measures of their food environment. The study area consisted of a contiguous geographical area encompassing a total of eight counties (seven rural and one urban) in the Midlands region of the state of South Carolina (SC). This was a supplement analyses related to a larger research effort developing measures of the built nutritional environment (15) (16) and examining perceptions, shopping behaviors, and diet in residents in the eight-county study region (21) (22). This study was approved by the University of South Carolina Institutional Review Board.

Study Participants

Recruitment of study participants was geographically-based in order to achieve a good spatial coverage of the entire study area. Selection was done through a random selection of landline telephone numbers with listed addresses restricted to 64 eligible ZIP codes within the study area with a goal of 15 respondents per ZIP code. Recruitment calls were made by the interviewing staff of the University of South Carolina (USC) Survey Research Laboratory (SRL) in which respondents were screened with respect to meeting the eligibility criteria including being a) at least 18 years, b) the primary food shopper, c) capable of speaking English, and d) living in the eight county study area. Of the 2,477 household telephone numbers screened, a total of 968 residents were eligible and completed the interview. However, there were 553 refusals, 377 ineligibles, and 579 of non-contact, unknown, or other status. Applying the American Association for Public Opinion Research Response Rate Formula 4 (23), we estimated a response rate of 47%,

which is very comparable to the 49% among landline households achieved in a recent evaluation of the Behavioral Risk Factor Surveillance System landline response rates conducted in 18 US states (24).

Perceived Fast Food Availability

Perceived fast food availability was ascertained by a previously validated question utilized in the telephone survey (25). Survey participants were asked to indicate the extent to which they agree with the following statement: "There are many opportunities to purchase fast foods in my neighborhood such as McDonald's, Taco Bell, KFC and takeout pizza places etc." Survey responses included "strongly agree"=1, "agree"=2, "neither agree or disagree (neutral)"=3, "disagree"=3, and "strongly disagree"=5. For analyses, responses were reverse coded to range from 0 – 4. A score of 0 indicated the worst perceived availability of fast food opportunities and 4 indicated the best perceived availability of fast food. The test-retest reliability of this question has been found to be good in our study sample, ICC=0.66 (0.54, 0.76) (21).

GIS-based Measures of the Food Environment

All geo-spatial analyses were conducted using ArcGIS 10.0 (ESRI Redlands, CA 2010). GIS-based measures were calculated using the geocoded residents' home address as the point of reference with a one mile street and road network buffer representing their neighborhood boundary. The addresses were then linked with an existing, validated geospatial database on the food retail outlets (15) (16) and the number of food outlets within the buffer and the distance to the nearest food outlet of each type calculated using

the shortest street distance based on the TIGER 2008 road network (U.S. Census TIGER/Line, 2008) (26). The food outlet types included franchised fast food restaurants, supermarkets, supercenters, warehouse clubs, convenience stores, drug and pharmacy stores, and dollar and variety stores. Supermarkets, supercenters, and warehouse clubs were all aggregated and considered as "supermarkets".

Resident Characteristics

The telephone survey also included questions on demographic and socio-economic characteristics. These questions were largely based on the Behavioral Risk Factor Surveillance Survey (BRFSS) (27). Age (in years) and the number of individuals living in a participant's household were both continuous variables. Race/ethnicity was categorized as Non-Hispanic White and Minority (Non-Hispanic Black or African American, Hispanic, and/or other). Annual household income was categorized as less than $20,000 or $20,000 or more. Education consisted of 3 groups: (1) not a high school graduate, (2) high school graduate or GED only, and (3) some college or higher. Partner and SNAP status were both dichotomous, coded as "yes" or "no". Employment status was a categorical variable grouped as employed, not employed, or retired. Each resident was classified individually with respect to level of urbanicity using the a 2010 U.S. Census defined urban classification (28) via a point-in-polygon operation within ArcGIS.

Statistical Analyses

Ordinary Least Square (OLS) regression models were used to assess the relationship between the GIS-based food retail outlet measures and the perceived

availability of fast food. Covariates included age, gender, race/ethnicity, education, employment, household income, SNAP utilization, partner status, household size, and level of urbanicity. Assumptions for OLS regression included linearity independent observations and linearity, homoscedasticity, and normality of the residuals. No violations were noted and multicolinearity was tested using variance inflation factors (VIF) and tolerance. To examine the independent influence of each GIS-based food outlet measure, without controlling for the other food outlet types, we examined separate models in which only one food outlet type was included in addition to covariates. Next, we examined models in which all GIS-based availability or accessibility measures for each food outlet type were included. The R^2 of each model was examined to determine how much each model explained the variance in perceived availability of fast food availability. The Unique R^2 was used to examine the unique contributions each GIS-based food outlet measure made in examining the variation in the perceived availability of fast foods. Final models were also stratified by urbanicity to examine relationships between GIS-based measures of the food environment and perceived availability of fast food in urban and non-urban residents separately.

Results

The majority of participants in our study were female (77.7%), Non-Hispanic White (65.5%), and lived in non-urban neighborhoods (77.5%) (Table 1). On average, participants were 57 years old and more than half had some college education or higher (53.1%). Only 11% of participants did not have a high school diploma or GED. Nearly 23% of participants were unemployed, 32% retired, and 29% had a household income

less than $20,000 per year. Sixty-four percent had a spouse or partner and on average, each household included 2.5 residents.

The mean number of food outlets in participants' neighborhoods was quite low, ranging from 0.1 outlet within 1 mile of a participant's home for supermarkets to 0.9 for convenience stores (Table 2). The mean number of franchised fast food restaurants was only 0.6. Many participants did not have fast food restaurants (84%), supermarkets (88.7%), and other food outlet types near their home. The mean distance to the nearest fast food restaurant for participants was 6.1 miles while the distances for other food outlets ranged from 2.9 miles for convenience stores to 7.8 miles for a drug and pharmacy stores. Finally, the mean perceived availability of fast food opportunities score was 1.9 on a scale of 0 to 4 for the entire study sample.

As shown in Table 3, both the number of fast food restaurants and distance to the nearest fast food restaurant were significantly associated with perceived availability of fast food (β =0.11, p-value=0.0005 and β =-0.07, p-value<0.0001, respectively). Similarly, the number of supermarkets, convenience stores, and drug and pharmacy stores all had a significant positive association with perceived fast food availability, whereas the distance to these other food outlet types had a significant negative association with perceived fast food availability. 15 to 20% of the variation was explained in all models. However, the unique contribution of each of the GIS-based measures was quite small, ranging from 1 to 5% using the distance to the nearest measures and 0.4 to 2% using the number of outlets.

Results of two final OLS models accounting for GIS-based measures for all food outlet types are displayed in Table 4. Only one significant relationship remained, i.e. the

number of drug and pharmacy stores had a significant positive association with perceived fast food opportunity (β=0.44, p-value=0.0021), though the unique R2 was very low at 1%. However in non-urban residents, there was a significant positive association between number of franchised fast food outlets and perceived availability of fast food opportunities (β=0.20, p-value=0.0367). However, fast food outlets only accounted for 1% of the variation.

Overall, distance to the nearest franchised fast food restaurant did not have a significant relationship with perceived availability of fast food when accounting for distance to all other food outlet types. Significant relationships were found between distance to nearest supermarket and drug and pharmacy stores (β=-0.08, p-value=0.0003 and β=-0.03, p-value=0.0403, respectively). However, neither food outlet type measure explained greater than 1% of the variation. Additionally, when stratifying by urbanicity, this relationship was not observed in urban residents.

Discussion

To the best of our knowledge, this is the first study to examine the relationship between perceived fast food opportunities and exposure to fast food outlets as measured by GIS. Neither the number of fast food outlets in a person's neighborhood nor the distance to the nearest fast food restaurant was independently associated with perceived fast food opportunities in this study once one controlled for the co-location of other food outlet types. GIS-based measures of fast food restaurants did not seem to contribute to how individuals perceive fast food availability in their neighborhood. Surprisingly, other

food outlets such as drug and pharmacy stores and supermarkets did exhibit some significant associations with perceived fast food availability.

Visits to fast food restaurants and fast food consumption have increased dramatically over the past 40 years (29,30) (31,32). Over thirty-seven percent of sales of meals and snacks away from home are at food venues such as fast food restaurants (2). Researchers have linked frequent fast food consumption with a less healthful, high-calorie diet and increased BMI (33) (34) (35) (36) (37) (38) (39) (40) (41). However, when relating fast food restaurant availability, diet quality, and weight status, the findings have been varied (4) (7) (5) (33) (42) (43) (44) (45) (8) (46) (47). Inconsistencies in the literature demonstrate a need to investigate valid and reliable measures of the food environment in order to shape strategies to improve individuals' food choices.

We have previously examined the association between participants' self-reported presence of a fast food restaurant and GIS-based presence. There, the participants were asked a factual-sounding question whether they had a fast food restaurant within a mile of their home. We found that participants' had a very accurate recollection (percent agreement of 83.5%) when reporting the presence or absence of a fast food restaurant within 1 mile of their home [Barnes2013]. Findings suggested that individuals have a good idea of what is physically present in their neighborhood environment. However, when asked a more opinion-oriented question on rating their opportunities to purchase fast food, we found that GIS-based measures were not good predictors. Thus, we conclude that a person's perception of opportunities to purchase fast food is a different concept than a person's perceived presence of a fast food outlet. Individual's personal preferences, lifestyle, and behaviors may better predict individuals' perceived availability

of fast food. Future studies using perception measures should carefully consider the questions utilized and not assume a correlation or substitution for GIS-based measures or vice versa.

A novel aspect of this study was that we also considered the association between perceived fast food availability and other types of food outlets such as supermarkets, convenience stores, and dollar and variety stores. It has been suggested in the literature that venues such as supermarkets and convenience stores which can contain "delis" and takeaway food items could be considered 'non-traditional' fast food venues (18). In addition, dollar and variety and drug and pharmacy stores have shelf space and freezer coolers available in which takeaway food items could be displayed. It could be the case that in our study population, individuals living in closer proximity to supermarkets and drug stores rated the perceived availability of fast food higher by considering such amenities. Other strengths of this study is the use of a validated questionnaire examining the perceived fast food opportunities (21), and the use of validated, GIS data on food outlets (15) (16). Our study also included two GIS-based measures. Moreover, our study included GIS of availability i.e. number of food outlets and the distance to nearest food outlet in the analyses. Lastly, our study area contained both urban and non-urban communities.

Nonetheless there are several imitations to our study. Our survey sample was limited to the primary food shoppers of their household and consisted of older adults who may or may not eat out as much as younger adults or individuals living in the household. Thus, our findings may not be generalizable. Secondly, the perceived fast food opportunity measure was self-report and could be open to biases. Individuals'

perceptions of what constitutes a fast food restaurant may differ from the examples provided in the survey. For example, individuals may consider different food outlets such as sit down restaurants or supermarket delis as fast food. Additionally, individuals may overestimate the size of a 1mile buffer or 20 minute walk around their home and associate the question on fast food opportunities much more broadly.

In this study, we examined the relationship between perceived fast food availability and GIS-based measures of fast food restaurants and other food outlet types. We had hypothesized that GIS-based measures of food outlets would be strong predictors of individual's perceived access to fast food in their neighborhood instead we found no significant association when controlling for all other food outlet types. Findings from this study could be helpful in providing a direction for future studies that aim to capture what factors, whether personal, environmental, or both, influence dietary behavior and obesity. Moreover, these results emphasize that future studies may have to consider both perceived and GIS-based measures of the food environment because there may not be a direct correlation between the two types of measurement (7) (9,48).

Table 6.1. Descriptive Statistics of Residents' Characteristics, N=705

		n (%) or **Mean (SD)**
Age (years)		**56.5 (14.7)**
Gender	Male	157 (22.3)
	Female	548 (77.7)
Race/Ethnicity	Minority (NHB, Hispanic, or Other)	243 (34.5)
	NHW	462 (65.5)
Education	< HS diploma or GED	80 (11.4)
	HS diploma or GED	251 (35.6)
	Some College or Higher	374 (53.1)
Employment Status	Not Employed	159 (22.6)
	Retired	222 (31.5)
	Employed	324 (46.0)
Household Income	< $20,000 per year	204 (28.9)
	≥ $20,000 per year	501 (71.1)
SNAP Status	No	635 (90.1)
	Yes	70 (9.9)
Spouse or Partner	No	253 (35.9)
	Yes	452 (64.1)
# of Household Members		**2.5 (1.4)**
Urbanicity	Non-Urban	558 (79.1)
	Urban	147 (20.9)

Table 6.2. Descriptive Statistics of Perceived and GIS-based Food Environment Measures, N=705

	Mean (SD)
Perceived Availability of Healthy Foods	
Fast Food Opportunity (Scoring Range: 0-4)	1.9 (1.5)
GIS-based Food Outlet Measures	
Availability of Retail Food Outlets (Number *within 1 mile buffer*)	
Franchised Fast Food	0.6 (1.8)
Supermarkets	0.1 (0.5)
Convenience	0.9 (1.9)
Drug and Pharmacy	0.2 (0.6)
Dollar and Variety	0.2 (0.7)
Accessibility of Retail Food Outlets (Distance to nearest *in miles*)	
Franchised Fast Food	6.1 (5.1)
Supermarkets	5.9 (4.5)
Convenience	2.9 (2.6)
Drug and Pharmacy	7.8 (5.9)
Dollar and Variety	5.1 (4.1)

Table 6.3. Relationship Between GIS-based Food Outlet Measures and Perceived Fast Food Opportunities, For Each Food Outlet Type Separately, N=705

	Unique R^2	β	SE	P-value	Model R^2
Availability of Retail Food Outlets (Number *within 1 mile buffer*)					
Franchised Fast Food	*0.01*	**0.11**	**0.03**	**0.0005**	*0.16*
Supermarkets	*0.01*	**0.30**	**0.12**	**0.0122**	*0.16*
Convenience	*0.01*	**0.07**	**0.03**	**0.0172**	*0.15*
Drug and Pharmacy	*0.02*	**0.44**	**0.10**	**<0.0001**	*0.17*
Dollar and Variety	*0.004*	0.14	0.08	0.06285	*0.15*
Accessibility of Retail Food Outlets (Distance to nearest *in miles*)					
Franchised Fast Food	*0.04*	**-0.07**	**0.01**	**<0.0001**	*0.19*
Supermarkets	*0.05*	**-0.08**	**0.01**	**<0.0001**	*0.20*
Convenience	*0.01*	**-0.06**	**0.02**	**0.0095**	*0.16*
Drug and Pharmacy	*0.04*	**-0.06**	**0.01**	**<0.0001**	*0.19*
Dollar and Variety	*0.02*	**-0.05**	**0.01**	**0.0003**	*0.16*

Note: All models adjusted for age, gender, race/ethnicity, education, employment status, household income, SNAP status, spouse or partner, # of household members, and urbanicity

Table 6.4. Relationship Between GIS-based Food Outlet Measures and Perceived Fast Food Opportunities, All Food Outlet Types, N=705

	All*				**Urban** N=147				**Non-Urban** N=558			
	Unique R^2	β	SE	P-value	Unique R^2	β	SE	P-value	Unique R^2	β	SE	P-value
Availability of Retail Food Outlets (Number *within 1 mile buffer*)												
Franchised Fast Food	0.003	0.07	0.04	0.0918	0.006	0.05	0.05	0.3275	0.01	**0.20**	**0.09**	**0.0367**
Supermarkets	0.0001	-0.05	0.16	0.7506	0.004	-0.15	0.18	0.3992	0.0003	0.13	0.31	0.6781
Convenience	0.001	-0.05	0.05	0.3008	0.01	-0.08	0.06	0.1681	0.0001	-0.02	0.07	0.8347
Drug and Pharmacy	0.01	**0.44**	**0.14**	**0.0021**	0.08	**0.63**	**0.17**	**0.0004**	0.006	0.43	0.23	0.0573
Dollar and Variety	0.0000003	-0.002	0.10	0.9870	0.003	0.13	0.18	0.4886	0.002	-0.19	0.16	0.2408
Model R^2	*0.17*				*0.21*				*0.08*			
Accessibility of Retail Food Outlets (Distance to nearest *in miles*)												
Franchised Fast Food	0.001	-0.01	0.02	0.4596	0.0002	-0.04	0.21	0.8401	0.001	-0.01	0.02	0.4346
Supermarkets	0.01	**-0.08**	**0.02**	**0.0003**	0.004	-0.17	0.19	0.3767	0.02	**-0.08**	**0.02**	**0.0005**
Convenience	0.00004	0.005	0.03	0.8604	0.006	0.18	0.17	0.2835	0.0002	0.01	0.03	0.7464
Drug and Pharmacy	0.005	**-0.03**	**0.01**	**0.0403**	0.02	-0.32	0.17	0.0697	0.005	-0.02	0.01	0.0923
Dollar and Variety	0.004	0.04	0.02	0.0734	0.002	-0.10	0.16	0.5266	0.007	0.04	0.02	0.0639
Model R^2	*0.21*				*0.28*				*0.12*			

Note. All models adjusted age, gender, race/ethnicity, education, employment status, household income, SNAP status, spouse or partner, and # of household members

*Adjusted for urbanicity

References

1. Richardson AS, Boone-Heinonen J, Popkin BM, Gordon-Larsen P: Neighborhood fast food restaurants and fast food consumption: a national study. *BMC Public Health* 11:543, 2011

2. Hearst MO, Harnack LJ, Bauer KW, Earnest AA, French SA, Michael OJ: Nutritional quality at eight u.s. Fast-food chains: 14-year trends. *Am J Prev Med* 44:589-594, 2013

3. Economic Research Service USDoAU: Diet quality and food consumption: food and nutrient intake tables. *Economic Research Service* 2011

4. Fraser LK, Edwards KL, Cade J, Clarke GP: The geography of Fast Food outlets: a review. *Int J Environ Res Public Health* 7:2290-2308, 2010

5. Fleischhacker SE, Evenson KR, Rodriguez DA, Ammerman AS: A systematic review of fast food access studies. *Obes Rev* 12:e460-e471, 2011

6. Guthrie JF, Lin BH, Frazao E: Role of food prepared away from home in the American diet, 1977-78 versus 1994-96: changes and consequences. *J Nutr Educ Behav* 34:140-150, 2002

7. Caspi CE, Sorensen G, Subramanian SV, Kawachi I: The local food environment and diet: a systematic review. *Health Place* 18:1172-1187, 2012

8. Jeffery RW, Baxter J, McGuire M, Linde J: Are fast food restaurants an environmental risk factor for obesity? *Int J Behav Nutr Phys Act* 3:2, 2006

9. Moore LV, ez Roux AV, Nettleton JA, Jacobs DR, Franco M: Fast-food consumption, diet quality, and neighborhood exposure to fast food: the multi-ethnic study of atherosclerosis. *Am J Epidemiol* 170:29-36, 2009

10. Paquet C, Daniel M, Knauper B, Gauvin L, Kestens Y, Dube L: Interactive effects of reward sensitivity and residential fast-food restaurant exposure on fast-food consumption. *Am J Clin Nutr* 91:771-776, 2010

11. Inglis V, Ball K, Crawford D: Socioeconomic variations in women's diets: what is the role of perceptions of the local food environment? *J Epidemiol Community Health* 62:191-197, 2008

12. Thornton LE, Pearce JR, Kavanagh AM: Using Geographic Information Systems (GIS) to assess the role of the built environment in influencing obesity: a glossary. *Int J Behav Nutr Phys Act* 8:71, 2011

13. Charreire H, Casey R, Salze P, Simon C, Chaix B, Banos A, Badariotti D, Weber C, Oppert JM: Measuring the food environment using geographical information systems: a methodological review. *Public Health Nutr* 13:1773-1785, 2010

14. Larson NI, Story MT, Nelson MC: Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med* 36:74-81, 2009

15. Liese AD, Colabianchi N, Lamichhane AP, Barnes TL, Hibbert JD, Porter DE, Nichols MD, Lawson AB: Validation of 3 food outlet databases: completeness and geospatial accuracy in rural and urban food environments. *Am J Epidemiol* 172:1324-1333, 2010

16. Liese AD, Barnes TL, Lamichhane AP, Hibbert JD, Colabianchi N, and Lawson AB. Characterizing the Food Retail Environment: Impact of Count, Type and Geospatial Error in Two Secondary Data Sources. Journal of Nutrition Education and Behavior . 2013.

17. Ho SY, Wong BY, Lo WS, Mak KK, Thomas GN, Lam TH: Neighbourhood food environment and dietary intakes in adolescents: sex and perceived family affluence as moderators. *Int J Pediatr Obes* 5:420-427, 2010

18. Sharkey JR, Johnson CM, Dean WR, Horel SA: Focusing on fast food restaurants alone underestimates the relationship between neighborhood deprivation and exposure to fast food in a large rural area. *Nutr J* 10:10, 2011

19. Sharkey JR, Johnson CM, Dean WR, Horel SA: Association between proximity to and coverage of traditional fast-food restaurants and non-traditional fast-food outlets and fast-food consumption among rural adults. *Int J Health Geogr* 10:37, 2011

20. Ma X, Barnes TL, Freedman DA, Bell BA, Colabianchi N, and Liese AD. Test-retest reliability of a questionnaire measuring perceptions of neighborhood food environment. Health & Place . 2013.

21. Liese AD, Bell BA, Barnes TL, Colabianchi N, Hibbert JD, Blake CE, and Freedman DA. Environmental influences on fruit and vegetable intake: Results from a path analytic model. American Journal of Preventive Medicine . 2013.

22. American Association for Public Opinion Research (AAPOR). Standard Definitions, Final Dispositions of Case Codes and Outcome Rates for Surveys. American Association for Public Opinion Research . 2011.

23. Hu SS, Balluz L, Battaglia MP, Frankel MR: Improving public health surveillance using a dual-frame survey of landline and cell phone numbers. *Am J Epidemiol* 173:703-711, 2011

24. Echeverria SE, ez-Roux AV, Link BG: Reliability of self-reported neighborhood characteristics. *J Urban Health* 81:682-701, 2004

25. United States Bureau of Census. 2008 TIGER/Line Shapefiles. 12-8-2008.

26. Centers for Disease Control and Prevention (CDC): Behavioral Risk Factor Surveillance System Survey Data. [article online], 2011.

27. Washington State Department of Health: Guidelines for Using Rural-Urban Classification Systems for Public Health Assessment. [article online], 2009. Accessed 23 December 2009

28. Dave JM, An LC, Jeffery RW, Ahluwalia JS: Relationship of attitudes toward fast food and frequency of fast-food intake in adults. *Obesity (Silver Spring)* 17:1164-1170, 2009

29. Clauson A: Spotlight on national food spending. *Food Rev* 23:15-17, 2000

30. National Restaurant Association: Restaurant Industry Pocket Factbook. *National Restaurant Association: Washington, DC* 2008

31. Guthrie JF, Lin BH, Frazao E: Role of food prepared away from home in the American diet, 1977-78 versus 1994-96: changes and consequences. *J Nutr Educ Behav* 34:140-150, 2002

32. Powell LM, Chaloupka FJ, Bao Y: The availability of fast-food and full-service restaurants in the United States: associations with neighborhood characteristics. *Am J Prev Med* 33:S240-S245, 2007

33. Pereira MA, Kartashov AI, Ebbeling CB, Van HL, Slattery ML, Jacobs DR, Jr., Ludwig DS: Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet* 365:36-42, 2005

34. Duffey KJ, Gordon-Larsen P, Jacobs DR, Jr., Williams OD, Popkin BM: Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the Coronary Artery Risk Development in Young Adults Study. *Am J Clin Nutr* 85:201-208, 2007

35. French SA, Harnack L, Jeffery RW: Fast food restaurant use among women in the Pound of Prevention study: dietary, behavioral and demographic correlates. *Int J Obes Relat Metab Disord* 24:1353-1359, 2000

36. Binkley JK, Eales J, Jekanowski M: The relation between dietary change and rising US obesity. *Int J Obes Relat Metab Disord* 24:1032-1039, 2000

37. French SA, Story M, Neumark-Sztainer D, Fulkerson JA, Hannan P: Fast food restaurant use among adolescents: associations with nutrient intake, food choices and behavioral and psychosocial variables. *Int J Obes Relat Metab Disord* 25:1823-1833, 2001

38. Paeratakul S, Ferdinand DP, Champagne CM, Ryan DH, Bray GA: Fast-food consumption among US adults and children: dietary and nutrient intake profile. *J Am Diet Assoc* 103:1332-1338, 2003

39. Bowman SA, Vinyard BT: Fast food consumption of U.S. adults: impact on energy and nutrient intakes and overweight status. *J Am Coll Nutr* 23:163-168, 2004

40. Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS: Effects of fast-food consumption on energy intake and diet quality among children in a national household survey. *Pediatrics* 113:112-118, 2004

41. Morland K, Wing S, Diez RA, Poole C: Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med* 22:23-29, 2002

42. Burdette HL, Whitaker RC: Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. *Prev Med* 38:57-63, 2004

43. Sturm R, Datar A: Body mass index in elementary school children, metropolitan area food prices and food outlet density. *Public Health* 119:1059-1068, 2005

44. Powell LM, Auld MC, Chaloupka FJ, O'Malley PM, Johnston LD: Associations between access to food stores and adolescent body mass index. *Am J Prev Med* 33:S301-S307, 2007

45. Mehta NK, Chang VW: Weight status and restaurant availability a multilevel analysis. *Am J Prev Med* 34:127-133, 2008

46. Maddock J: The relationship between obesity and the prevalence of fast food restaurants: state-level analysis. *Am J Health Promot* 19:137-143, 2004

47. Moore LV, ez Roux AV, Brines S: Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment. *J Urban Health* 85:206-216, 2008

CHAPTER 7

SUMMARY AND CONCLUSIONS

Overview of Key Findings

This dissertation examined associations between the perceived and built food environment. Specifically, GIS-based availability and accessibility measures of food outlets were related to the perceived presence of food outlets, perceived availability of healthy foods, and perceived availability of fast foods.

Over the past few years, both perceived and GIS-based measures have been used in food environment research, however, the use of GIS-based measures to characterize the availability of food outlets outnumbers self-report or questionnaire-based measures 57 to 10 (130) (146). Researchers have tended to rely on GIS-based measures because these methods have been quicker and cheaper than administering questionnaires and, in the majority of cases, easier than ground-truthing and auditing the food environment (141) (146). Another benefit of characterizing the food environment via GIS is that it can be performed retrospectively or prospectively through data linkage. However, as pointed out by Caspi and colleagues, GIS measures should be used when the attributes provided by such measures are theoretically relevant (146). It may be the case, that GIS-based measures cannot account for all factors and influences in a person's food environment.

Moreover, some aspects of the food environment may only be derived from asking individuals' about their neighborhood (146).

There were many hypotheses related to the aims of this dissertation. First, it was hypothesized that individuals would have a moderate agreement between the perceived and GIS-based presence of food outlets, with supermarkets having the best agreement. It was also hypothesized that there would be a significant positive association between the perception of healthy foods and the availability and accessibility of supermarkets. Contrarily, it was hypothesized there would be a negative association between the perception of healthy foods and the availability of "less healthy" food outlets such as convenience stores, drug and pharmacies, dollar and variety, and fast food restaurants. Lastly, it was hypothesized that a positive association would exist between the perceived availability of fast food opportunities and GIS-based availability and accessibility measures of fast food restaurants.

Findings did suggest that individuals were quite aware of the presence of food outlets in their neighborhood food environment, especially for supermarkets, convenience stores, and fast food restaurants. Specifically, residents had a percent agreement for food outlets ranging from 67.1% to 83.5% using a standard 1 mile GIS-based neighborhood buffer size. Additionally, sensitivities ranged from 82.3% to 92.5% with supermarkets and convenience stores having the highest sensitivity values (92.5% and 90.1%, respectively). Percent agreement and sensitivity for fast food restaurants were 83.5% and 82.3%, respectively using a 1 mile buffer size. To the best of my knowledge, only two studies have included analyses comparing perceived and GIS-based presence of food outlets directly (45,147). In a sample of 1393 women, aged 18 – 65 years, in Melbourne,

Australia, Williams and colleagues found that the match between the perceived and objective food environment was quite poor, reporting approximately 50% of women had a complete agreement or disagreement between their perceptions and objective measure of supermarket presence within 800m (~0.5 miles) of their home (45). For a fast food store, the match was only 40%. This outcome is much different than our study in which we had a good percent agreement for both supermarkets and fast food restaurants (77.9% and 83.5%, respectively).

However, when examining the relationship between the GIS-based measures of food outlets and the perceived availability of healthy foods, only the accessibility of supermarkets was significantly associated with perceived availability of healthy foods (β=-0.16, P-value=0.0022) when controlling for other food outlets. In addition, the accessibility of dollar and variety stores and fast food restaurants were significantly associated with perceived availability of healthy foods, but dollar and variety stores were in the opposite direction as expected (β=-0.15, P-value=0.0044 and β=0.11, P-value=0.0136, respectively). These findings differ from previous studies that have suggested a significant positive association between supermarket availability, either by presence or number of stores, with perceived availability of healthy foods (50) (53). In a study by Moore et al., residents living in areas with lower densities of supermarkets reported a lower selection and availability of healthy foods compared to areas with high densities of supermarkets (50). However, this study did not adjust for other food outlet types in their analyses. In another study, Gustafson et al. found that individuals with a convenience store and a supercenter present had higher odds of perceiving their neighborhood high in healthy food availability (53). However in the same study,

Gustafson et al. did not find a significant association when considering supermarkets, supercenters, and convenience stores separately (53).

As for fast food, there was no association found in this dissertation between the GIS-based availability and accessibility measures of fast food and the perceived availability of fast food restaurants (β=0.07, P-value=0.0918 and (β=-0.01, P-value=0.4596) when controlling for all other food outlets. This was surprising given our hypothesis; however, to the best of my knowledge, this is one of the first studies to examine the relationship between perceived fast food opportunities and GIS-based exposure to fast food outlets directly.

Overall, these results call into question whether or not GIS-based food outlet measures are good indicators of how individuals may rate the availability of fruits and vegetables or fast food opportunities in their neighborhood food environment. Moreover, it is reasonable to suggest that a person's perception of healthy foods and fast food opportunities measure entirely different aspects of the food environment compared to the GIS-based availability and accessibility measures. This is in contrast to how individuals perceive the presence of a food outlet in their neighborhood. In that case, individuals' seem to know whether or not a supermarket or fast food restaurant is presence, but the presence or proximity of those outlets are not significantly associated with perceived availability of healthy foods or fast food. It may also be reasonable to suggest that researchers should consider using a mixed-approach when characterizing individuals' food environments, using both objective, GIS-based measures and individuals' perceptions of their environment. Perception measures should carefully consider the

questions utilized and not assume a correlation or substitution for GIS-based measures or vice versa.

Results may also point out some difference between using an availability measure versus accessibility when describing the food environment. In these analyses, more significant associations were found using the accessibility measure i.e. distance to nearest outlet than the availability or number of food outlets within a person's neighborhood.

Neighborhood Size

This dissertation also examined whether using different boundaries to define the GIS-based neighborhood would change the agreement between perceived presence of food outlet types and the GIS-based presence. Findings indicated that validity statistics significantly improved when increasing the buffer sizes. Thus, individuals may be overestimating the size of their neighborhood instead of conceptualizing a buffer of one mile as requested by the question. Researchers should consider using larger buffer sizes i.e. 2 miles or conduct sensitivity analyses in order to find the appropriate parameters that best define the neighborhood food environments of their study populations.

Urban and Non-Urban Differences

Finally, this dissertation compared the associations between the perceived and GIS-based food environment between urban and non-urban residents. When examining perceived and GIS-based presence, urban residents had a significantly higher sensitivity and positive predictive values and lower specificity values than non-urban residents. However, only the percent agreement between perceived and GIS-based presence of

supermarkets was significantly different between urban and non-urban residents using a 1 mile GIS-based buffer. Differences between urban and non-urban residents had also been observed in testing the reliability of the perception questions themselves. Specifically, urban residents demonstrated better reliability on questions pertaining to opportunities to purchase fast food and perceived presence of a supercenter than non-urban residents (148). Additionally, the ICCs for the other perceptions questions including healthy food availability were consistently higher for urban than rural residents (148).

The relationship between GIS-based availability and accessibility measures of food outlets and perceived availability of healthy foods seemed to differ by urbanicity in a few food outlet types. Specifically, the magnitude of the relationship between the accessibility of supermarkets and perceived availability of healthy foods was much higher in urban residents compared to non-urban residents. Additionally, the accessibility of dollar and variety stores and accessibility of fast food restaurants were only significantly associated with perceived availability of healthy foods in non-urban residents compared to urban residents. Differences have been found in other studies. For example, the study by Moore et al. included residents living in North Carolina, Maryland, and New York with areas differing in population density and urbanicity(50). Given these differences, Moore and et al. found evidence of regional variation in the relationship between store densities and perceived availability of healthy foods. For example, supermarket density was found to be most strongly associated with perceived availability of healthy foods in North Carolina compared to the higher populated areas of Maryland and New York (50). However, in these analyses when stratifying by urbanicity

the relationship between the availability (number of stores) for any food outlet type was not significantly associated with perceived availability of healthy foods in urban residents in the final model. In contrast, the perceived availability of healthy foods increased significantly as the number of convenience stores increased in non-urban residents.

Lastly, there was also a significant association found between the availability of fast food restaurants and the availability fast food opportunities in non-urban residents compared to urban residents, but not when modeling the entire study sample.

REFERENCES

1. Flegal KM, Carroll MD, Kit BK, Ogden CL: Prevalence of obesity and trends in the distribution of body mass index among US adults, 1999-2010. *JAMA* 307:491-497, 2012

2. Ogden CL, Carroll MD, Kit BK, Flegal KM: Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. *JAMA* 307:483-490, 2012

3. Flegal KM, Carroll MD, Ogden CL, Curtin LR: Prevalence and trends in obesity among US adults, 1999-2008. *JAMA* 303:235-241, 2010

4. Flegal KM: Epidemiologic aspects of overweight and obesity in the United States. *Physiol Behav* 86:599-602, 2005

5. Ogden CL, Lamb MM, Carroll MD, Flegal KM: Obesity and socioeconomic status in adults: United States, 2005-2008. *NCHS Data Brief*1-8, 2010

6. Ogden CL, Lamb MM, Carroll MD, Flegal KM: Obesity and socioeconomic status in children and adolescents: United States, 2005-2008. *NCHS Data Brief*1-8, 2010

7. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM: Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA* 295:1549-1555, 2006

8. Wang MC, Kim S, Gonzalez AA, MacLeod KE, Winkleby MA: Socioeconomic and food-related physical characteristics of the neighbourhood environment are associated with body mass index. *J Epidemiol Community Health* 61:491-498, 2007

9. Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, Marks JS: Prevalence of obesity, diabetes, and obesity-related health risk factors, 2001. *JAMA* 289:76-79, 2003

10. Mokdad AH, Marks JS, Stroup DF, Gerberding JL: Actual causes of death in the United States, 2000. *JAMA* 291:1238-1245, 2004

11. Papas MA, Alberg AJ, Ewing R, Helzlsouer KJ, Gary TL, Klassen AC: The built environment and obesity. *Epidemiol Rev* 29:129-143, 2007

12. Cerin E, Frank LD, Sallis JF, Saelens BE, Conway TL, Chapman JE, Glanz K: From neighborhood design and food options to residents' weight status. *Appetite* 56:693-703, 2011

13. Larson N, Story M: A review of environmental influences on food choices. *Ann Behav Med* 38 Suppl 1:S56-S73, 2009

14. Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K: Creating healthy food and eating environments: policy and environmental approaches. *Annu Rev Public Health* 29:253-272, 2008

15. Black JL, Macinko J: Neighborhoods and obesity. *Nutr Rev* 66:2-20, 2008

16. Glanz K, Sallis JF, Saelens BE, Frank LD: Nutrition Environment Measures Survey in stores (NEMS-S): development and evaluation. *Am J Prev Med* 32:282-289, 2007

17. Glanz K, Sallis JF, Saelens BE, Frank LD: Healthy nutrition environments: concepts and measures. *Am J Health Promot* 19:330-3, ii, 2005

18. Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J: An ecological approach to creating active living communities. *Annu Rev Public Health* 27:297-322, 2006

19. Sallis JF, Glanz K: The role of built environments in physical activity, eating, and obesity in childhood. *Future Child* 16:89-108, 2006

20. Larson NI, Story MT, Nelson MC: Neighborhood environments: disparities in access to healthy foods in the U.S. *Am J Prev Med* 36:74-81, 2009

21. U.S.Department of Agriculture (USDA): Accessing to Affordable and Nutritious Food: Measuring and Understanding Food Deserts and Their Consequences: Report to Congress. *United States Department of Agriculture Economic Research Service AP-036* 2009

22. Gantner L.A., Olson CM, Frongillo EA, Wells NM: Prevalence of Nontraditional Food Stores and Distance to Healthy Foods in a Rural Food Environment. *Journal of Hunger & Environmental Nutrition* 6:279-293, 2011

23. Powell LM, Chaloupka FJ, Bao Y: The availability of fast-food and full-service restaurants in the United States: associations with neighborhood characteristics. *Am J Prev Med* 33:S240-S245, 2007

24. Beaulac J, Kristjansson E, Cummins S: A systematic review of food deserts, 1966-2007. *Prev Chronic Dis* 6:A105, 2009

25. Walker RE, Keane CR, Burke JG: Disparities and access to healthy food in the United States: A review of food deserts literature. *Health Place* 16:876-884, 2010

26. Morland K, Wing S, Diez RA, Poole C: Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med* 22:23-29, 2002

27. Morland K, ez Roux AV, Wing S: Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. *Am J Prev Med* 30:333-339, 2006

28. Zenk SN, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML: Neighborhood racial composition, neighborhood poverty, and the spatial accessibility of supermarkets in metropolitan Detroit. *Am J Public Health* 95:660-667, 2005

29. Franco M, ez-Roux AV, Nettleton JA, Lazo M, Brancati F, Caballero B, Glass T, Moore LV: Availability of healthy foods and dietary patterns: the Multi-Ethnic Study of Atherosclerosis. *Am J Clin Nutr* 89:897-904, 2009

30. Moore LV, ez Roux AV, Nettleton JA, Jacobs DR, Jr.: Associations of the local food environment with diet quality--a comparison of assessments based on surveys and geographic information systems: the multi-ethnic study of atherosclerosis. *Am J Epidemiol* 167:917-924, 2008

31. Powell LM, Slater S, Mirtcheva D, Bao Y, Chaloupka FJ: Food store availability and neighborhood characteristics in the United States. *Prev Med* 44:189-195, 2007

32. Laraia BA, Siega-Riz AM, Kaufman JS, Jones SJ: Proximity of supermarkets is positively associated with diet quality index for pregnancy. *Prev Med* 39:869-875, 2004

33. Edmonds J, Baranowski T, Baranowski J, Cullen KW, Myres D: Ecological and socioeconomic correlates of fruit, juice, and vegetable consumption among African-American boys. *Prev Med* 32:476-481, 2001

34. Cheadle A, Psaty BM, Curry S, Wagner E, Diehr P, Koepsell T, Kristal A: Community-level comparisons between the grocery store environment and individual dietary practices. *Prev Med* 20:250-261, 1991

35. Powell LM, Auld MC, Chaloupka FJ, O'Malley PM, Johnston LD: Associations between access to food stores and adolescent body mass index. *Am J Prev Med* 33:S301-S307, 2007

36. Centers for Disease Control and Prevention (CDC): Communities Putting Prevention to Work. [article online], 2011. Accessed 27 April 2011

37. Centers for Disease and Control and Prevention: Children's Food Environment State Indicator Report, 2011. [article online], 2011.

38. U.S.Department of Agriculture ERS: USDA Food Desert Locator. [article online], 2011. Available from http://www.ers.usda.gov/data/fooddesert.

39. Economic Research Service USDoA: USDA Food Environment Atlas. *Economic Research Service,U S Department of Agriculture* 2011

40. Bustillos B, Sharkey JR, Anding J, McIntosh A: Availability of more healthful food alternatives in traditional, convenience, and nontraditional types of food stores in two rural Texas counties. *J Am Diet Assoc* 109:883-889, 2009

41. Freedman DA, Bell BA: Access to healthful foods among an urban food insecure population: perceptions versus reality. *J Urban Health* 86:825-838, 2009

42. Charreire H, Casey R, Salze P, Simon C, Chaix B, Banos A, Badariotti D, Weber C, Oppert JM: Measuring the food environment using geographical information systems: a methodological review. *Public Health Nutr* 13:1773-1785, 2010

43. Thornton LE, Pearce JR, Kavanagh AM: Using Geographic Information Systems (GIS) to assess the role of the built environment in influencing obesity: a glossary. *Int J Behav Nutr Phys Act* 8:71, 2011

44. Van ME, Lawson AB, Colabianchi N, Nichols M, Hibbert J, Porter D, Liese AD: Spatial Accessibility and Availability Measures and Statistical Properties in the Food Environment. *Spat Spatiotemporal Epidemiol* 2:35-47, 2011

45. Williams LK, Thornton L, Ball K, Crawford D: Is the objective food environment associated with perceptions of the food environment? *Public Health Nutr*1-8, 2011

46. Morland K, Wing S, Diez RA: The contextual effect of the local food environment on residents' diets: the atherosclerosis risk in communities study. *Am J Public Health* 92:1761-1767, 2002

47. Garasky, S., Morton, L. W., and Greder, K. The food environment and food insercurity: perceptions of rural, suburban, and urban food pantry clients in Iowa. Family Economics and Nutrition Review 16(2), 41-48. 2004.

48. The Food Trust: Food Geography: How Food Access Affects Diet and Health. *The Food Trust and The Philadelphia Health Management Corporation* 2006

49. Giskes K, Van Lenthe FJ, Brug J, Mackenbach JP, Turrell G: Socioeconomic inequalities in food purchasing: the contribution of respondent-perceived and actual (objectively measured) price and availability of foods. *Prev Med* 45:41-48, 2007

50. Moore LV, ez Roux AV, Brines S: Comparing Perception-Based and Geographic Information System (GIS)-based characterizations of the local food environment. *J Urban Health* 85:206-216, 2008

51. Moore LV, ez Roux AV, Nettleton JA, Jacobs DR, Franco M: Fast-food consumption, diet quality, and neighborhood exposure to fast food: the multi-ethnic study of atherosclerosis. *Am J Epidemiol* 170:29-36, 2009

52. Sharkey JR, Johnson CM, Dean WR: Food access and perceptions of the community and household food environment as correlates of fruit and vegetable intake among rural seniors. *BMC Geriatr* 10:32, 2010

53. Gustafson AA, Sharkey J, Samuel-Hodge CD, Jones-Smith J, Folds MC, Cai J, Ammerman AS: Perceived and objective measures of the food store environment and the association with weight and diet among low-income women in North Carolina. *Public Health Nutr*1-7, 2011

54. Freedman DA: Local food environments: they're all stocked differently. *Am J Community Psychol* 44:382-393, 2009

55. Odoms-Young AM, Zenk S, Mason M: Measuring food availability and access in African-American communities: implications for intervention and policy. *Am J Prev Med* 36:S145-S150, 2009

56. Maley M, Warren BS, Devine CM: Perceptions of the environment for eating and exercise in a rural community. *J Nutr Educ Behav* 42:185-191, 2010

57. kumar S, Quinn S.C., Kriska AM, Thomas SB: "Food is directed to the area":African Americans' perceptions of the neighborhood nutrition environment in Pittsburgh. *Health & Place* 17:370-378, 2011

58. Liese, A. D., Bell, B. A., Nichols, M., Colabianchi, N., Hibbert, J., Freedman, D., Barnes, T., and French, S. Relative Influence of Supermarket Availability and Access, Perceptions, and Shopping Behaviors on Fruit and Vegetable Intake. International Society for Behavioral Nutrition and Physical Activity (ISBNPA). Abstract . 2011. 6-15-2011.

59. Liese, A. D., Colabianchi, N., Hibbert, J., Nichols, M., and Freedman, D. A. Association of supermarket availability, accessibility, and utilization with dietary intake. Experimental Biology (American Society for Nutrition), Washington, DC, April 9 - 13, 2011 . 2011.

60. Echeverria SE, ez-Roux AV, Link BG: Reliability of self-reported neighborhood characteristics. *J Urban Health* 81:682-701, 2004

61. Liese AD, Colabianchi N, Lamichhane AP, Barnes TL, Hibbert JD, Porter DE, Nichols MD, Lawson AB: Validation of 3 food outlet databases: completeness and geospatial accuracy in rural and urban food environments. *Am J Epidemiol* 172:1324-1333, 2010

62. Centers for Disease Control and Prevention (CDC): Behavioral Risk Factor Surveillance System Survey Data. [article online], 2011.

63. Washington State Department of Health: Guidelines for Using Rural-Urban Classification Systems for Public Health Assessment. [article online], 2009. Accessed 23 December 2009

64. Colabianchi N, Dowda M, Pfeiffer KA, Porter DE, Almeida MJ, Pate RR: Towards an understanding of salient neighborhood boundaries: adolescent reports of an easy walking distance and convenient driving distance. *Int J Behav Nutr Phys Act* 4:66, 2007

65. Boone-Heinonen J, Popkin BM, Song Y, Gordon-Larsen P: What neighborhood area captures built environment features related to adolescent physical activity? *Health Place* 16:1280-1286, 2010

66. Smith G, Gidlow C, Davey R, Foster C: What is my walking neighbourhood? A pilot study of English adults' definitions of their local walking neighbourhoods. *Int J Behav Nutr Phys Act* 7:34, 2010

67. Centers for Disease and Control and Prevention: *Centers for Disease Control and Prevention's Division of Nutrition, Physical Activity, and Obesity (CDC DNPAO)* 2011

68. Macintyre S, Ellaway A, Cummins S: Place effects on health: how can we conceptualise, operationalise and measure them? *Soc Sci Med* 55:125-139, 2002

69. Turrell G, Blakely T, Patterson C, Oldenburg B: A multilevel analysis of socioeconomic (small area) differences in household food purchasing behaviour. *J Epidemiol Community Health* 58:208-215, 2004

70. Morland KB, Evenson KR: Obesity prevalence and the local food environment. *Health Place* 15:491-495, 2009

71. Centers for Disease Control and Prevention: About healthy places. [article online], 2011. Available from http://www.cdc.gov/healthyplaces/about.htm.

72. Booth KM, Pinkston MM, Poston WS: Obesity and the built environment. *J Am Diet Assoc* 105:S110-S117, 2005

73. Cummins S, Macintyre S: Food environments and obesity--neighbourhood or nation? *Int J Epidemiol* 35:100-104, 2006

74. Popkin BM, Duffey K, Gordon-Larsen P: Environmental influences on food choice, physical activity and energy balance. *Physiol Behav* 86:603-613, 2005

75. Liu GC, Cunningham C, Downs SM, Marrero DG, Fineberg N: A spatial analysis of obesogenic environments for children. *Proc AMIA Symp*459-463, 2002

76. Inagami S, Cohen DA, Finch BK, Asch SM: You are where you shop: grocery store locations, weight, and neighborhoods. *Am J Prev Med* 31:10-17, 2006

77. Sturm R, Datar A: Body mass index in elementary school children, metropolitan area food prices and food outlet density. *Public Health* 119:1059-1068, 2005

78. Jeffery RW, Baxter J, McGuire M, Linde J: Are fast food restaurants an environmental risk factor for obesity? *Int J Behav Nutr Phys Act* 3:2, 2006

79. Rutt CD, Coleman KJ: Examining the relationships among built environment, physical activity, and body mass index in El Paso, TX. *Prev Med* 40:831-841, 2005

80. Maddock J: The relationship between obesity and the prevalence of fast food restaurants: state-level analysis. *Am J Health Promot* 19:137-143, 2004

81. Haslam DW, James WP: Obesity. *Lancet* 366:1197-1209, 2005

82. Grundy SM: Obesity, metabolic syndrome, and cardiovascular disease. *J Clin Endocrinol Metab* 89:2595-2600, 2004

83. Bray GA: Medical consequences of obesity. *J Clin Endocrinol Metab* 89:2583-2589, 2004

84. Barness LA, Opitz JM, Gilbert-Barness E: Obesity: genetic, molecular, and environmental aspects. *Am J Med Genet A* 143A:3016-3034, 2007

85. Swinburn B, Egger G, Raza F: Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med* 29:563-570, 1999

86. Elinder LS, Jansson M: Obesogenic environments--aspects on measurement and indicators. *Public Health Nutr* 12:307-315, 2009

87. U.S.Department of Agriculture (USDA): Diet Quality and Food Consumption: Dietary Patterns, Diet Quality, and Obesity. *United States Department of Agriculture, Economic Research Service* 2011

88. McLeroy KR, Bibeau D, Steckler A, Glanz K: An ecological perspective on health promotion programs. *Health Educ Q* 15:351-377, 1988

89. Bodor JN, Rose D, Farley TA, Swalm C, Scott SK: Neighbourhood fruit and vegetable availability and consumption: the role of small food stores in an urban environment. *Public Health Nutr* 11:413-420, 2008

90. Leone AF, Rigby S, Betterley C, Park S, Kurtz H, Johnson MA, Lee JS: Store type and demographic influence on the availability and price of healthful foods, leon county, Florida, 2008. *Prev Chronic Dis* 8:A140, 2011

91. Franco M, ez Roux AV, Glass TA, Caballero B, Brancati FL: Neighborhood characteristics and availability of healthy foods in Baltimore. *Am J Prev Med* 35:561-567, 2008

92. Block D, Kouba J: A comparison of the availability and affordability of a market basket in two communities in the Chicago area. *Public Health Nutr* 9:837-845, 2006

93. Zenk SN, Schulz AJ, Israel BA, James SA, Bao S, Wilson ML: Fruit and vegetable access differs by community racial composition and socioeconomic position in Detroit, Michigan. *Ethn Dis* 16:275-280, 2006

94. Rose D, Richards R: Food store access and household fruit and vegetable use among participants in the US Food Stamp Program. *Public Health Nutr* 7:1081-1088, 2004

95. Jago R, Baranowski T, Baranowski JC, Cullen KW, Thompson D: Distance to food stores & adolescent male fruit and vegetable consumption: mediation effects. *Int J Behav Nutr Phys Act* 4:35, 2007

96. Martinez SW: The US Food Marketing System: Recent Developments, 1997-2006. *Washington, DC: US Department of Agriculture Economic Research Service Economic Research Report Number 42* 2007

97. Saelens BE, Glanz K, Sallis JF, Frank LD: Nutrition Environment Measures Study in restaurants (NEMS-R): development and evaluation. *Am J Prev Med* 32:273-281, 2007

98. North American Industry Classification System. [article online], 2007. Available from http://www.census.gov/eos/wwww/naics/. Accessed 28 November 2008

99. Lee SH, Rowan MT, Powell LM, Newman S, Klassen AC, Frick KD, Anderson J, Gittelsohn J: Characteristics of prepared food sources in low-income neighborhoods of Baltimore City. *Ecol Food Nutr* 49:409-430, 2010

100. Pereira MA, Kartashov AI, Ebbeling CB, Van HL, Slattery ML, Jacobs DR, Jr., Ludwig DS: Fast-food habits, weight gain, and insulin resistance (the CARDIA study): 15-year prospective analysis. *Lancet* 365:36-42, 2005

101. Duffey KJ, Gordon-Larsen P, Jacobs DR, Jr., Williams OD, Popkin BM: Differential associations of fast food and restaurant food consumption with 3-y change in body mass index: the Coronary Artery Risk Development in Young Adults Study. *Am J Clin Nutr* 85:201-208, 2007

102. French SA, Harnack L, Jeffery RW: Fast food restaurant use among women in the Pound of Prevention study: dietary, behavioral and demographic correlates. *Int J Obes Relat Metab Disord* 24:1353-1359, 2000

103. Binkley JK, Eales J, Jekanowski M: The relation between dietary change and rising US obesity. *Int J Obes Relat Metab Disord* 24:1032-1039, 2000

104. French SA, Story M, Neumark-Sztainer D, Fulkerson JA, Hannan P: Fast food restaurant use among adolescents: associations with nutrient intake, food choices and behavioral and psychosocial variables. *Int J Obes Relat Metab Disord* 25:1823-1833, 2001

105. Paeratakul S, Ferdinand DP, Champagne CM, Ryan DH, Bray GA: Fast-food consumption among US adults and children: dietary and nutrient intake profile. *J Am Diet Assoc* 103:1332-1338, 2003

106. Bowman SA, Vinyard BT: Fast food consumption of U.S. adults: impact on energy and nutrient intakes and overweight status. *J Am Coll Nutr* 23:163-168, 2004

107. Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS: Effects of fast-food consumption on energy intake and diet quality among children in a national household survey. *Pediatrics* 113:112-118, 2004

108. Burdette HL, Whitaker RC: Neighborhood playgrounds, fast food restaurants, and crime: relationships to overweight in low-income preschool children. *Prev Med* 38:57-63, 2004

109. Powell LM, Auld MC, Chaloupka FJ, O'Malley PM, Johnston LD: Access to fast food and food prices: relationship with fruit and vegetable consumption and overweight among adolescents. *Adv Health Econ Health Serv Res* 17:23-48, 2007

110. Mehta NK, Chang VW: Weight status and restaurant availability a multilevel analysis. *Am J Prev Med* 34:127-133, 2008

111. Michimi A, Wimberly MC: Associations of supermarket accessibility with obesity and fruit and vegetable consumption in the conterminous United States. *Int J Health Geogr* 9:49, 2010

112. Cummins S, Macintyre S: "Food deserts"--evidence and assumption in health policy making. *BMJ* 325:436-438, 2002

113. Centers for Disease Control and Prevention (CDC): State Indicator Report on Fruits and Vegetables. [article online], 2009. Accessed 28 April 2011

114. Zenk SN, Schulz AJ, Matthews SA, Odoms-Young A, Wilbur J, Wegrzyn L, Gibbs K, Braunschweig C, Stokes C: Activity space environment and dietary and physical activity behaviors: a pilot study. *Health Place* 17:1150-1161, 2011

115. Feng J, Glass TA, Curriero FC, Stewart WF, Schwartz BS: The built environment and obesity: a systematic review of the epidemiologic evidence. *Health Place* 16:175-190, 2010

116. Leal C, Chaix B: The influence of geographic life environments on cardiometabolic risk factors: a systematic review, a methodological assessment and a research agenda. *Obes Rev* 12:217-230, 2011

117. Chaskin RJ: Defining Neighborhood. In *Planning and Urban Design Standards*. Lewis M, Klein B, Eds. Hoboken, NJ, John Wiley & Sons, 2006,

118. Forsyth A, Lytle L, Riper DV: Finding food: Issues and challenges in using Geographic Information Systems to measure food access. *J Transp Land Use* 3:43-65, 2010

119. Timperio A, Ball K, Roberts R, Campbell K, Andrianopoulos N, Crawford D: Children's fruit and vegetable intake: associations with the neighbourhood food environment. *Prev Med* 46:331-335, 2008

120. Zenk SN, Powell LM: US secondary schools and food outlets. *Health Place* 14:336-346, 2008

121. Austin SB, Melly SJ, Sanchez BN, Patel A, Buka S, Gortmaker SL: Clustering of fast-food restaurants around schools: a novel application of spatial statistics to the study of food environments. *Am J Public Health* 95:1575-1581, 2005

122. Larsen K, Gilliland J: Mapping the evolution of 'food deserts' in a Canadian city: supermarket accessibility in London, Ontario, 1961-2005. *Int J Health Geogr* 7:16, 2008

123. O'Dwyer LA, Coveney J: Scoping supermarket availability and accessibility by socio-economic status in Adelaide. *Health Promot J Austr* 17:240-246, 2006

124. Winkler E, Turrell G, Patterson C: Does living in a disadvantaged area mean fewer opportunities to purchase fresh fruit and vegetables in the area? Findings from the Brisbane food study. *Health Place* 12:306-319, 2006

125. Smoyer-Tomic KE, Spence JC, Raine KD, Amrhein C, Cameron N, Yasenovskiy V, Cutumisu N, Hemphill E, Healy J: The association between neighborhood socioeconomic status and exposure to supermarkets and fast food outlets. *Health Place* 14:740-754, 2008

126. Block JP, Scribner RA, DeSalvo KB: Fast food, race/ethnicity, and income: a geographic analysis. *Am J Prev Med* 27:211-217, 2004

127. Inglis V, Ball K, Crawford D: Socioeconomic variations in women's diets: what is the role of perceptions of the local food environment? *J Epidemiol Community Health* 62:191-197, 2008

128. Lytle LA, Murray DM, Perry CL, Story M, Birnbaum AS, Kubik MY, Varnell S: School-based approaches to affect adolescents' diets: results from the TEENS study. *Health Educ Behav* 31:270-287, 2004

129. Sharkey JR: Measuring potential access to food stores and food-service places in rural areas in the U.S. *Am J Prev Med* 36:S151-S155, 2009

130. McKinnon RA, Reedy J, Morrissette MA, Lytle LA, Yaroch AL: Measures of the food environment: a compilation of the literature, 1990-2007. *Am J Prev Med* 36:S124-S133, 2009

131. Mujahid MS, ez Roux AV, Morenoff JD, Raghunathan T: Assessing the measurement properties of neighborhood scales: from psychometrics to ecometrics. *Am J Epidemiol* 165:858-867, 2007

132. Raudenbush SW, Sampson RJ: Ecometrics: toward a science of assessing ecological settings, with application to the systematic social observation of neighborhoods. *Sociol Method* 29:1-41, 1999

133. Kirtland KA, Porter DE, Addy CL, Neet MJ, Williams JE, Sharpe PA, Neff LJ, Kimsey CD, Jr., Ainsworth BE: Environmental measures of physical activity supports: perception versus reality. *Am J Prev Med* 24:323-331, 2003

134. Sallis JF: Measuring physical activity environments: a brief history. *Am J Prev Med* 36:S86-S92, 2009

135. Brownson RC, Hoehner CM, Day K, Forsyth A, Sallis JF: Measuring the built environment for physical activity: state of the science. *Am J Prev Med* 36:S99-123, 2009

136. Inglis V, Ball K, Crawford D: Socioeconomic variations in women's diets: what is the role of perceptions of the local food environment? *J Epidemiol Community Health* 62:191-197, 2008

137. Keita AD, Casazza K, Thomas O, Fernandez JR: Neighborhood perceptions affect dietary behaviors and diet quality. *J Nutr Educ Behav* 43:244-250, 2011

138. Zenk SN, Schulz AJ, Lachance LL, Mentz G, Kannan S, Ridella W, Galea S: Multilevel correlates of satisfaction with neighborhood availability of fresh fruits and vegetables. *Ann Behav Med* 38:48-59, 2009

139. Zenk SN, Odoms-Young AM, Dallas C, Hardy E, Watkins A, Hoskins-Wroten J, Holland L: "You have to hunt for the fruits, the vegetables": environmental barriers and adaptive strategies to acquire food in a low-income African American neighborhood. *Health Educ Behav* 38:282-292, 2011

140. U.S.Census Bureau: U.S. Census Summary File 1. [article online], 2000. Available from http://www.census.gov.

141. Liese AD, Barnes TL, Lamichhane AP, Hibbert JD, Colabianchi N, and Lawson AB. Characterizing the Food Retail Environment: Impact of Count, Type and

Geospatial Error in Two Secondary Data Sources. Journal of Nutrition Education and Behavior . 2013.

142. United States Bureau of Census. 2008 TIGER/Line Shapefiles. 12-8-2008.

143. Cummins SC, McKay L, Macintyre S: McDonald's restaurants and neighborhood deprivation in Scotland and England. *Am J Prev Med* 29:308-310, 2005

144. Liu GC, Wilson JS, Qi R, Ying J: Green neighborhoods, food retail and childhood overweight: differences by population density. *Am J Health Promot* 21:317-325, 2007

145. Sharkey JR, Horel S, Han D, Huber JC, Jr.: Association between neighborhood need and spatial access to food stores and fast food restaurants in neighborhoods of colonias. *Int J Health Geogr* 8:9, 2009

146. Caspi CE, Sorensen G, Subramanian SV, Kawachi I: The local food environment and diet: a systematic review. *Health Place* 18:1172-1187, 2012

147. Caspi CE, Kawachi I, Subramanian SV, Adamkiewicz G, Sorensen G: The relationship between diet and perceived and objective access to supermarkets among low-income housing residents. *Soc Sci Med* 75:1254-1262, 2012

148. Ma X, Barnes TL, Freedman DA, Bell BA, Colabianchi N, and Liese AD. Test-retest reliability of a questionnaire measuring perceptions of neighborhood food environment. Health & Place . 2013.